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The Health of Southern Forests

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Forest Service
Southern Region

The Health of Southern Forests

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Introduction

To understand why we monitor the health of the forests, it is best to take a historical perspective. When the European settlers first began to colonize the new world, the vast forests of North America were viewed more as obstacles to be conquered than resources to be exploited. In the earliest days of colonization, the pioneers had little opportunity to even capitalize on the potential wealth offered by the virgin wilderness woodlands. Mere survival was paramount to economic development per se, and the quicker and more efficiently the forests could be cleared for life-sustaining agricultural development, the better. By contemporary conservation standards, pioneer land-clearing methods were often abominable. Huge areas were frequently burned, often causing irreparable damage to the fragile underlying soil. Slash and burn agriculture all too often resulted in widespread soil erosion and silting of rivers and streams. So complete was the ecosystem damage in some areas that biologists can sometimes only speculate on the makeup of the fauna and flora just prior to the impact of European colonization.

Unfortunately, land management practices over the next hundred years improved little over those of the earlier first ancestors. Vast southern forests were typically clearcut with reckless abandon, in many cases for conversion to cotton fields. Nevertheless, settlers had a newfound appreciation for the economic value of wood. Now there was practical use for the trees. Timber helped fuel the burgeoning southern economy. Trees meant fuel for steamboats and cotton mills. They meant charcoal for pig-iron works. They meant lumber for building construction and export. Thus, the agricultural South found new uses (albeit not a love) for its forests. So complete was the deforestation in the early to mid-1800's that the percentage of land covered by Southern Piedmont forests is far greater today than in 1860.

In the Reconstruction Era, much of the focus in the highlands shifted from clearing land for agriculture to direct logging. Much of the Southern Appalachian mountains offered little appeal from a farming perspective, but high quality hardwoods (and in the highest elevations, spruce-fir forests) attracted timber barons, eager to feed the growing American industrial engine. Once again, reckless abandon held sway over any semblance of environmentally responsible logging. Clearing the mountain forests was back-breaking, dangerous work, but the steam engine and more sophisticated engineering methods permitted logging of all but the most remote coves and steepest hillsides.

Around the turn of the century, wealthy industrialist and visionary conservationist George Vanderbilt purchased a huge tract of land in western North Carolina. Vanderbilt was appalled by the land abuse that had taken place over much of his holdings. At the urging of the great American landscape architect Frederick Low Olmstead, he hired Gifford Pinchot, and later the German forester Dr. Carl Schenck, to assess and manage his property. Schenck soon realized that he needed skilled assistants to help him in this undertaking, but no professionally trained foresters were to be found in America. Thus, Schenck founded what was to be America's first forestry school near Asheville, North Carolina, in 1898. The first priority for Schenck's young foresters was conservation. Halting and repairing the massive land abuse was a Herculean undertaking. Eventually, a few foresters began to develop a special interest in inventory work. Most of the early surveys were for timber volume estimates, but the fledgling foresters also made notes on the health of the forest stands. Eventually these surveys evolved into more detailed documentation on the incidence of insect and disease conditions. Thus began the earliest contemporary forest health monitoring surveys.

An important milestone in the evolution of forest health monitoring was the increasing role of the Federal government in natural resource management. In the early 20th century, President Theodore Roosevelt, who shared the vision of pioneer conservationists like Schenck and Vanderbilt, worked to provide the government with broad conservation powers. Soon the United States Forest Service was born, and with it the genesis of a rich heritage of professional forestry, including area specialization ranging from wildlife management to forest economics to forest pathology.

Inventory was a high priority in the new Forest Service as surveyors set out to classify the nation's forests. Along the way they increasingly documented various facets of forest health. Forestry in America was rapidly improving, and American foresters were beginning to gain stature comparable to their European counterparts. Surveys no longer represented mere incidence reports, but began to take on statistical reliability. The country was forming the data base for what would be an index of change for all time.

In the 1930's President Franklin D. Roosevelt continued in the tradition of his uncle Theodore. Strengthening the Forest Service, FDR improved the Research branch. Forest Service researchers, in cooperation with colleagues in universities, developed increasingly reliable statistical survey

methods designed specifically for American forests.

With the end of World War II, the United States again turned its attention to its forest land, with special attention to southern forests. Piedmont forests still had not recovered from land abuse during the depression era, and President Dwight David Eisenhower signed legislation authorizing massive reforestation of eroded lands. Most of these trees were loblolly and shortleaf pines, which came to be known as "Eisenhower pines." Several of the newly planted lands were to become new National Forests. Meanwhile, forest entomology and pathology became increasingly sophisticated, and some of the most significant forestry research in America's history was published in the 1950's. Much of this work was of an inventory nature, and for the first time addressed specific insect and disease survey methods.

The 1960's saw a quantum leap in insect and disease survey procedures. The new Forest Service Pest Control Section worked closely with the Research Stations and other Forest Service units to develop sophisticated insect and disease survey procedures. Motivated largely by economics of timber production, these surveys were designed to obtain the most accurate data possible in the shortest amount of time. For the first time, aircraft became important survey tools. Pest Control quickly embraced the rapidly developing field of aerial photography, and foresters and pest specialists were publishing the most accurate and useful survey reports to date. Unknown to the surveyors of the era, an important watershed took place—publication of Rachel Carson's *Silent Spring*, the nonfiction exposé on pesticide pollution. This book would forever change the agency's approach to pest management, while giving birth to a movement known as "environmentalism."

Two milestones marked the 1970's: increasing sophistication in remote sensing and strengthening of State forestry agency programs. Most of the satellite technology to 1970 had been for experimental and military purposes. With the launch of Landsat and similar satellites, remote-sensing imagery for resource management became both useful and cost effective. While primitive by today's standards, the satellite technology of the era offered exciting survey possibilities, and the entomologists and pathologists of the time were quick to embrace it. Also in the 1970's, the State forestry agencies added forest pest specialists to their staffs and, in cooperation with the Forest Service, formed important relationships which endure to this day. The decade also saw the first widespread recognition of the importance of air pollution as a stressor of forests, and the first surveys were carried out to identify point-source pollution.

The geographic information system (GIS) was the hallmark of the 1980's. This elaborate computer system gave insight into stressor relationships undreamed of just a few years earlier. Through the power of high-speed computers, the process allowed "layers" of data to be displayed spatially and in tabular format, while giving investigators insight into the relationship between multiple, overlapping variables such as soil type, weather, forest type, and topography (*See Figure 1*). The decade also saw widespread recognition of the role of non-point-source air pollution as a stressor of southern forests.

Today, the most significant developments are perhaps not so much technical as political and social. Never before has the American public been so interested in the condition of its forest resources. Fueled by media reports of "acid rain," global warming, and massive clearing of tropical rain forests, pressure is increasing on today's resource managers to report on the status and condition of the woodlands under their charge. Fortunately, this intense interest coincides with the history's most sophisticated and accurate monitoring methodology. In the 1990's, we see the forest not only as an ecosystem in itself, but as a component of a complex, interlinked worldwide ecosystem. We view the forest as a type of bioindicator of planetary health, and resource management agencies around the world are cooperating to establish baseline standards to determine possible deviation from "normal" as time transpires.

This publication summarizes much of the data contained in a huge GIS data base known as the Southern Forest Atlas. Begun in the mid 80's this GIS represents the first central consolidation of a variety of interacting stressor factors, including weather, ozone, and numerous forest pests. Scientists and resource managers now can access this data base for a variety of purposes ranging from predictive modeling to analysis of historical trends.

Donald H. Marx
Frogmore, South Carolina, September 1995

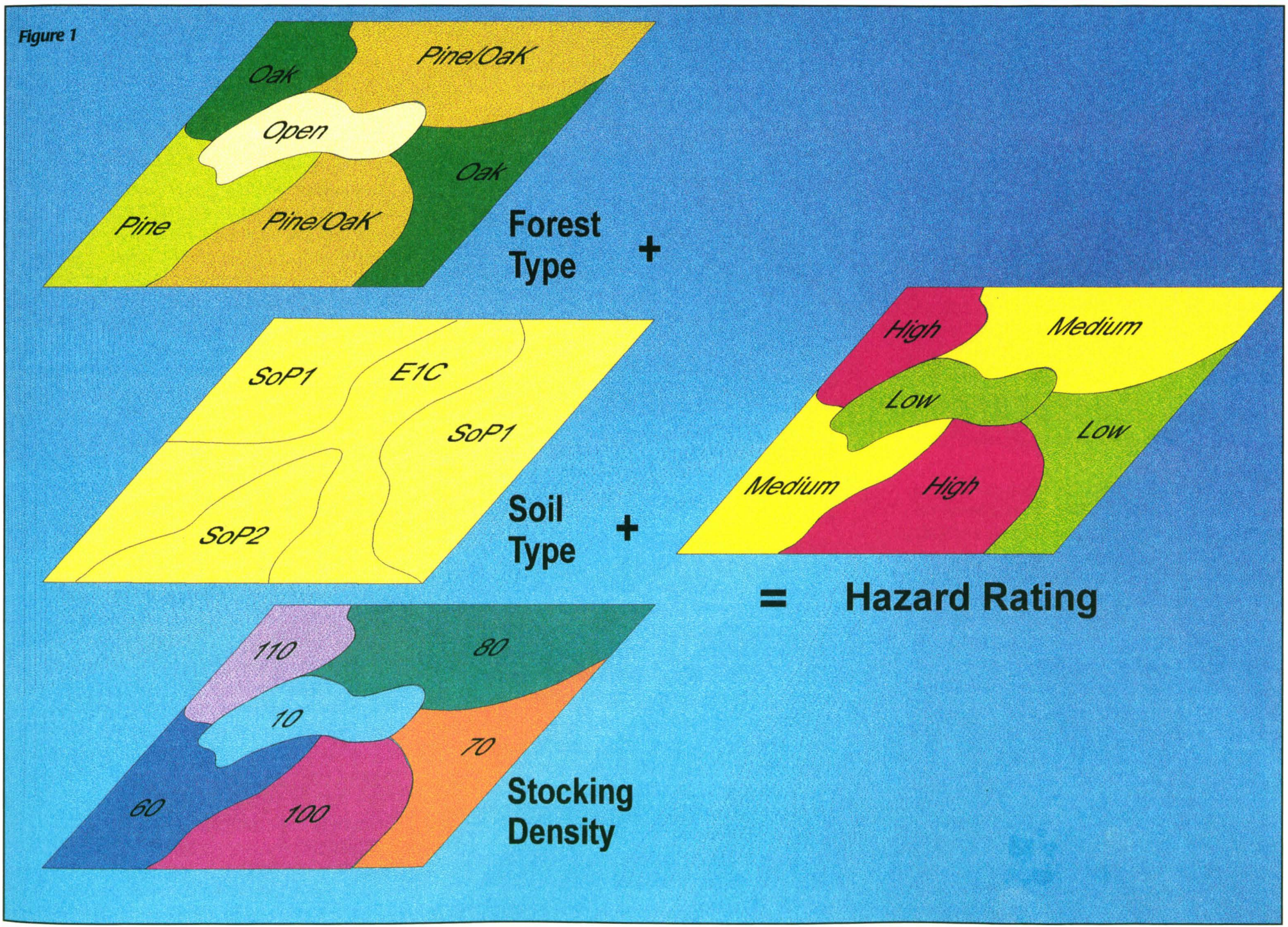


Figure 1
Oak
Pine/OaK
Open
Oak
Pine
Pine/OaK
Forest Type
+
SoP1
E1C
SoP1
SoP2
Soil Type
+
High
Medium
Low
Low
Medium
High
= Hazard Rating
110
80
10
70
60
100
Stocking Density

Forest Stressors and Why We Monitor Them

Information about forest stressors and the factors that influence them probably has expanded more in the past 25 years than in the entire previous century. Our knowledge of climatology, soils, pathogens, insects, plant physiology, anthropogenic influences, and other factors has increased at an almost geometric rate. Perhaps more importantly, scientists have come to appreciate the role that these stressors play in interaction with one another.

In other words, our knowledge of the cause-effect relationship is clearer than ever before. Earlier land managers and scientists often erred in assigning one condition as the cause (e.g., southern pine beetle) without recognizing the underlying influences that triggered the condition (e.g., not matching the planted tree species to the site). Today, investigative forest resource scientists take a much more holistic approach to analysis of conditions as reflected in stressed trees.

Coincident with this increased understanding of tree-environment dynamics has been a fortuitous and equally impressive ability to track, record, and analyze stressed conditions. This understanding has come none too soon. Without sophisticated detection and analysis equipment, the vast amounts of data accumulated over the past two or three decades could scarcely be tabulated, let alone analyzed and interpreted. To cope with the explosion of information, high-technology tools are necessities, not luxuries. Examples of such tools are geographic information systems (GIS), global positioning systems (GPS), satellite imagery, and highly refined aerial reconnaissance methods.

Our present ability to collect and tabulate an enormous volume of data has led to an opportunity probably never envisioned by most scientists in the first half of the 20th century—the capacity to perform complicated, computerized, statistical, and spatial analysis on investigations into large-scale environmental change. As just one example of such high-technology investigative work, scientists have given birth to a new branch of dendrochronology (the study of tree age) in which analyses are made of tree rings to determine the chemical composition of the environment decades ago so it can be compared with the composition today.

Many of these new analysis methods have applications not only with contemporary information but also with data chronicled long ago. Retired scientists are no doubt heartened to see their work reanalyzed and depicted using contemporary methodology. One example is historical records on the southern pine beetle included in figure 22.

Using modern tools and land managers, environmental scientists are establishing baseline data that doubtless will prove valuable in determining whether conditions such as global warming and tropical deforestation are impacting geographic areas ranging in size from a stand of white pine trees in North Carolina to the health of the entire planet earth.

As dramatic as advances have been in recent years, technology continues to grow more and more sophisticated at an exponential rate. Software and hardware engineers, photogrammetrists, statisticians, and environmental scientists are coordinating their efforts to maximize the utility of their different disciplines. So rapid are these advances that the technology described in this publication likely will become obsolete in a few years.

Forest health is important to the public in many ways, from the forest products used in everyday life to the quality of the environment. Also, the same insects and diseases that damage forests can affect trees in residential and other nonforest areas.

To assist readers of this publication who are not familiar with forestry terms, a glossary has been placed at the end of the text. A list of the common and scientific names of the pests and the hosts that are discussed appears in appendix A.

The Forest Health Unit and Its State and Federal Cooperators

The Southern Region Forest Health Unit (Forest Health) of the USDA Forest Service traces its roots to the early 1960's. Plagued by serious insect and disease outbreaks such as southern pine beetle, chestnut blight, fusiform rust, and gypsy moth, the Forest Service saw the need for a specialized unit to work exclusively on pest problems related to forest resource productivity and management.

The Forest Health Unit employs entomologists, pathologists, specialists in a geographic information system (GIS), and others to provide technical assistance in the prevention, detection, evaluation, and suppression of insect and disease problems in forests. Additional assistance is available in such areas as seed orchard pest management, nursery pest management, pesticide use, protection of wood-in-use, monitoring of insect and disease conditions, and cooperative pest management training programs for Federal and State personnel.

Forest Health maintains three offices in the Southern Region. Headquarters are in Atlanta, with field offices in Asheville, North Carolina, and Pineville, Louisiana. Forest Health also administers the Resistance Screening Center near Asheville, where seedlings are screened for genetic resistance to destructive diseases. Forest Health serves as a liaison between Federal and State agencies concerned with many facets of forest pest management.

Appendix B lists addresses of the Southern Region offices, as well as cooperating forestry agencies in States and Territories.

Forest Health Monitoring in the South

An important part of the Forest Health operation is the Forest Health Monitoring program (FHM). FHM is a consortium of many Federal and State agencies that work together to monitor, assess, and report on the status, changes, and long-term trends in the health of the nation's forest ecosystems. Although "forest health" can be defined in several ways, it is generally considered to include a balance among growth, mortality, and regeneration; appropriate biological diversity; and the ability to withstand and recover from the impacts of various stressors, such as insect or disease outbreaks, adverse weather and climate, and air pollution.

The FHM program is divided into two general parts: on-frame and off-frame.

"On-frame" refers to a network of survey plots installed at regular intervals across the United States. This plot network is administered and monitored by the USDA Forest Service, the Environmental Protection Agency (EPA), and participating State forestry agencies. At this writing, participating southern states are Alabama, Georgia, and Virginia. Data collected include observations on stand structure, growth, mortality, crown condition, damage, regeneration, biodiversity, wildlife habitat, soil characteristics, and indicator plants for air pollution.

The "off-frame" or "off-plot" component consists of aerial and other surveys of forested areas to detect and assess large-scale damage from insects, diseases, and other stressors.

Compilation of off-frame data is a highly cooperative effort, with coordination among numerous Federal and State agencies. In the South, participating States include Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia. Two Territories are administratively located in the Southern Region of the USDA Forest Service and participate in resource management activities: Puerto Rico and the U.S. Virgin Islands.

Federal cooperators in off-frame studies include the USDA Forest Service, the National Park Service, the Tennessee Valley Authority, Environmental Protection Agency, Fish and Wildlife Service of the Department of the Interior, Department of Defense, Department of Energy, National Oceanic and Atmospheric Administration (NOAA), and others.

Numerous universities across the South also participate through the development of survey, evaluation, and reporting systems that are important to the off-frame FHM program. The Forest Service and its cooperators throughout the South and the nation are working to standardize methods for off-frame surveys and reporting to ensure consistent and reliable data.

This publication reports exclusively on off-frame data, with emphasis on 12 of the more important stressors for which data are most reliable or for which data have been collected for periods sufficient to show trends over time. A list of common and scientific names of pests appears in appendix A, along with names of hosts.

In addition to the more important stressors, this publication includes brief discussions of four localized stressors.

The Role of State and Federal Cooperators

The monitoring and management of southern forests is a highly collaborative initiative. Federal and State agencies are equal partners in monitoring and managing the public's forest resources. State forestry agencies are integral to this effort, and all have a formal cooperative agreement with the USDA Forest Service.

In recent years, the Forest Service, State agencies, and Federal agencies other than the Forest Service have worked hard to standardize survey and reporting data. Standardization gives increased utility to this important information.

With increased computerization and other high-technology approaches to resource management and monitoring, cooperation and coordination have become more important. Through regular coordination meetings and standardization workshops, a variety of State and Federal specialists (including entomologists, pathologists, GIS specialists, engineers, and computer programmers) are helping to ensure that their publics are served with reliable and meaningful data that are collected in an economically responsible manner. The result is information that can be exchanged easily between compatible computer systems and interpreted consistently across State, regional, and ultimately international borders.

Using GIS to Monitor Stressors Affecting the Forest

Data collection on forest health in the 1960's consisted mainly of maps: topographical maps, road maps, and specialty maps showing the location and severity of forest pest problems. Information was collected primarily through visual observation, from low-flying aircraft or from ground surveys. During the 1960's, aerial photographs were added, most often in color or infrared. Sometimes photographs even replaced maps.

By the 1980's, the computer had become a prominent part of data collection. Maps and photos were still an integral part of the process, but the next critical part was the computer. Now, in the 1990's, data are increasingly collected and stored directly in the computer.

Data storage, along with the computer technology to analyze the data and to display information in map and tabular form, is the basis for a geographic information system (GIS). GIS is a support function that stores data and allows the analysis and

comparison of spatial and temporal relationships with one another, as well as with other features that affect forest health.

How does the Forest Service use GIS to access and monitor various conditions that affect the health of the forest? The first consideration is to determine what information is wanted.

In the case of Forest Health, what are the stressors (objects, events, and situations) that most likely affect forest health? Major stressors include insects and diseases, weather (e.g., drought or excessive rainfall, excessively high or low temperatures, ice), and soil conditions (e.g., high sand content, high clay content). In addition, the occurrence of high ozone levels has been suggested as a major forest-health stressor.

In developing a GIS to assess and monitor forest health, the Forest Health Unit established the following data bases for the 13 states in the Southern Region. The primary attributes of each data base are:

Forests

Forest distribution by county is shown

Attributes include:
22 Society of American Foresters cover types
Acres for each type
Volume (cubic feet per acre)

Soils

Coverage is from State Soil Geographic Database (STATSGO).

Attributes include:
Data on characteristics such as water content, pH, organic matter and clay are available at various soil depths.

Weather

Data base contains point and polygon coverages of weather data for all areas of the States in the Southern Region except western Oklahoma and Texas and northern Kentucky and Virginia. Data from 1951 through 1990 are currently available.

Attributes include:
Monthly averages and deviations from a long-term (1951 through 1990) average in a gridded format for the following climactic variables:
Precipitation
Maximum daily temperature
Minimum daily temperature
Relative humidity
Wind speed
Freezing precipitation

Pest stressors

Data exist for a number of pest stressors, including the gypsy moth, dogwood anthracnose, southern pine beetle, annosum root disease, and fusiform rust. Many of these stressors are discussed in more detail in this publication.

The Southern Forests

The forests in the southern United States are the most diverse and complex in all of North America. More tree species are found in the Great Smoky Mountains National Park than in all of Europe. Ranging from the subtropical cucumber tree to ancient palms to species such as the balsam fir that are more commonly thought of as typically Canadian, the highly varied southern forest ecosystems serve as hosts for an equally diverse assemblage of insects, diseases, and anthropogenic impacts.

Into this complex but delicately balanced system, several important arrivals have been added recently, including the gypsy moth, balsam woolly adelgid, butternut decline, and dogwood anthracnose. Complicated by man's activities, this "living laboratory" has experienced – and continues to experience – changes that compress eons of evolution into just a few years.

In the broadest terms, southern forests can be classed into four categories: hardwood, pine, mixed hardwood and pine, and spruce-fir. These four are sometimes further subdivided into still more classifications. Examples are southern bottomland hardwood versus upland hardwood and eastern white pine versus loblolly-shortleaf pine. ***Figure 2*** shows one classification system, based on data from the Society of American Foresters.

The present publication focuses on three of the four broad categories and on the insects, diseases, and other problems typically associated with these types.

Figure 2

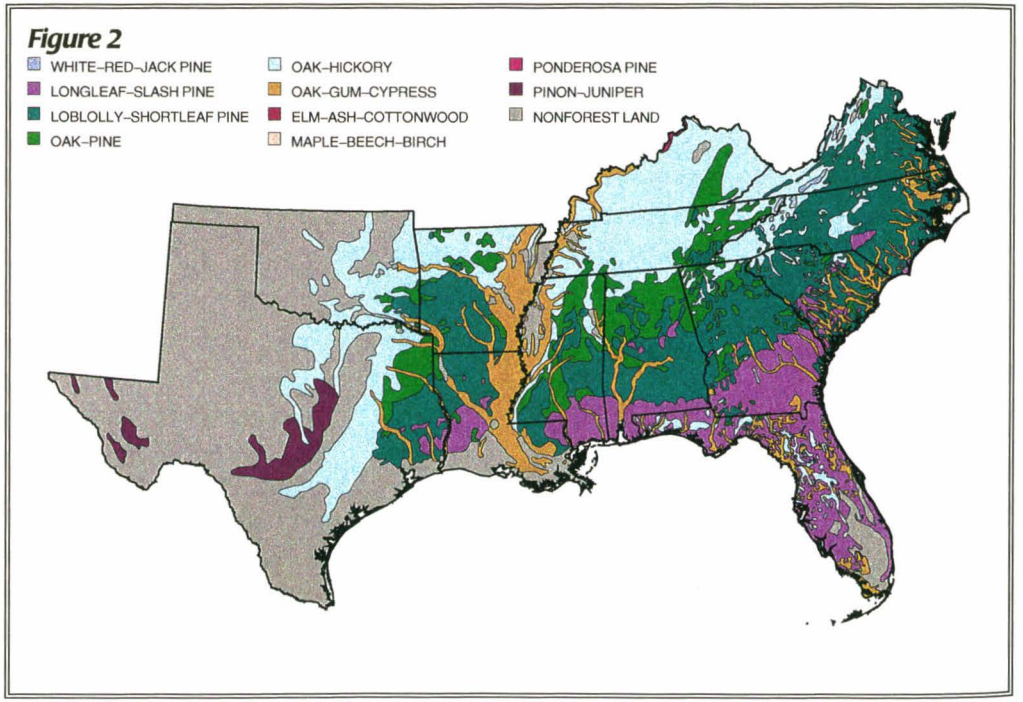


Figure 3

Except for the spruce-fir type, which is highly limited and confined to only the highest peaks in the southern Appalachian Mountains, southern forest types can be found spread across much of the region. Still, foresters typically associate the hardwood types with more mountainous areas (both the Ozarks and the Appalachian Mountains) or with rich bottomland sites such as the alluvial soils of the Mississippi delta. Pine and pine-hardwood types are most prominent in the Piedmont, coastal plains, and deep Gulf South.

Although each of the following sections of this publication discusses a particular forest stressor found in the South, the reader should realize that insects, diseases, and other forest and tree anomalies are often found in concert. For example, southern pine beetle is often associated with littleleaf disease. Man's activities, such as air pollution or soil degradation, can predispose forests and trees to a variety of insect and disease conditions.

Stressors of Hardwood Forests

Four stressors of hardwood forests in the South that have been emphasized by the Forest Health Monitoring program are butternut canker, dogwood anthracnose, gypsy moth, and oak decline.

Butternut Canker

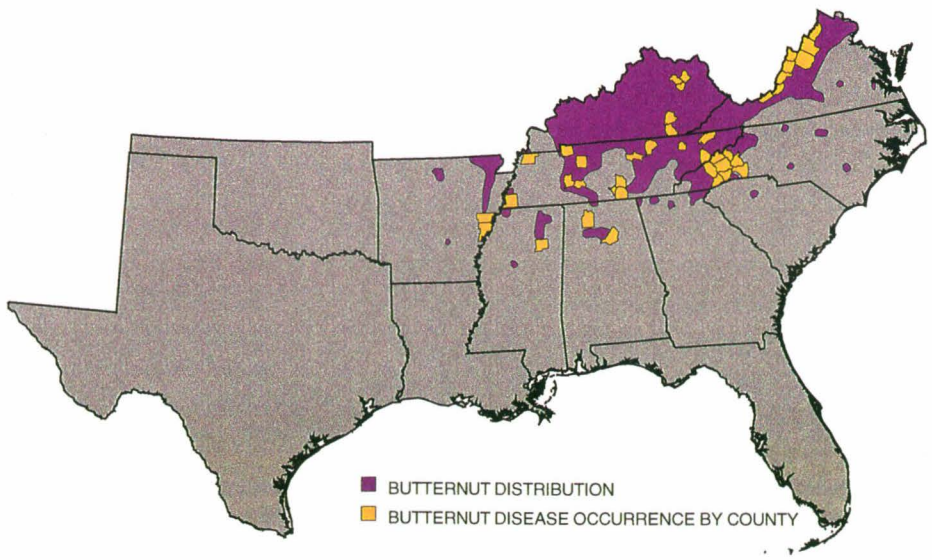
Butternut is being killed throughout its range by butternut decline, a disease that causes multiple cankers on the main stem and branches. Young cankers are elongated sunken areas, often with an inky black center and whitish margin. Peeling the bark reveals brown-to-black elliptical areas of killed cambium. Older branch and stem cankers are perennial, often covered by shredded bark and bordered by successive callus layers. ***Figure 3*** shows a butternut tree exhibiting typical symptoms of butternut canker.

Branch cankers usually occur first in the lower crown, and stem cankers develop later from spores washing down from cankers above. The fungus can survive and sporulate on dead trees for at least 20 months.

Spores of the causal fungus are disseminated from fruiting bodies by rain splash and possibly by insects. Produced throughout the growing season, the spores can survive and be dispersed long distances during weather conditions favorable to the disease (cool temperatures and overcast skies).

In 1978, the first survey for butternut canker throughout the eastern States was completed. Initially, an alert was sent to governments of each State in which butternut naturally occurs. This pest alert advised the States of the problem, gave some information on how to diagnose the condition initially, and requested that reports on infected counties be made to the Forest Service. If trees with signs of incipient infection with cankers were found, the USDA Forest Service requested cooperators to send

Figure 4



samples of the diseased material to its Forest Health Unit for laboratory culturing of the suspected pathogen.

Based on results of that initial survey and on more recent field evaluations by State and Federal Forest Health personnel, the disease appears to cover practically the entire range of butternut. ***Figure 4*** shows butternut distribution and confirmed disease by county.

Additionally, in 1990, the Forest Inventory and Analysis (FIA) group of the USDA Forest Service was requested to provide information on the change in the number of butternut 5 inches and larger in diameter in North Carolina and Virginia. The data from FIA show a 77 percent reduction in the number of butternut in these two states over the past 30 years. These changes may be attributable in part to causes other than butternut canker.

In March 1993, the United States Forest Service placed harvest restrictions on healthy butternut in national forests. Butternut is currently classified under category 2 on the list of endangered and threatened plants determined under the Endangered Species Act. Additional data on the health of butternut are being collected in several States to determine if butternut should be classified as a threatened species.

Although the complete field picture is unclear because of limited data, it appears that butternut canker has spread throughout the range of the tree in the South, except for some isolated pockets. In southern states with confirmed cases, the mortality in the last 30 years is estimated at 77 percent. These data have a large error potential because of the limited sample size.

Butternut, including regeneration, will be devastated by this disease in the years to come. Consequently, the species will be replaced by other hardwoods. Some hope lies in promising studies of genetic resistance. If and when resistant trees are found, they will be deployed in the forest. A butternut coalition is being formed, in part to look for and confirm resistant trees.

While no special survey methods for butternut are in development, technologies applicable to other pests should find applications in the butternut arena as well.

Dogwood Anthracnose

Dogwood anthracnose is a serious disease of flowering dogwoods. Since it was first reported in 1978, dogwood anthracnose has spread rapidly west and south from its northeastern origins. Some of the worst losses have been reported in the South, where the disease continues to intensify.

Aside from the aesthetic impact to both forest and shade trees, dogwood anthracnose can contribute to significant ecological disturbance. Many wildlife species are dependent on dogwood for food and cover.

Anthracnose infection begins in the leaves during the growing season ***(Figure 5)*** and spreads to twigs and branches. Branches die back to the main stem, resulting in cankers that kill the tree. In the South, mortality is most likely to occur in elevations above 3000 feet on all sites. Below 3000 feet, the damage is most severe on moist, cool sites. Shade increases the risk of infection and mortality.

Since the disease was first reported in northern Georgia and western North Carolina in 1987 and 1988, respectively, it has spread very rapidly throughout the entire southern Appalachian range. Data from intensive evaluation plots in the South reflect the virulence of this pathogen. From 1988 to 1992, mortality rates jumped from 0 to 17 percent, and severe infection rates from 4 to 17 percent.

From 1988 through 1994, surveys and impact assessments were funded in the South through a special technology development project. State cooperators throughout the Southern Region routinely reported confirmed dogwood anthracnose infections on a county-by-county basis. This information continues to be reported to the Forest Health field office of the USDA Forest Service in Asheville, North

Figure 5

Carolina, which maintains the data and prepares an annual report.

The origin of dogwood anthracnose is open to some speculation. To some pathologists, the speed with which this disease is spreading suggests a foreign pathogen introduced into the United States. It is also possible, however, that a change in the environment altered the established host-parasite relationship, enabling a previously innocuous fungus to become a killing pathogen.

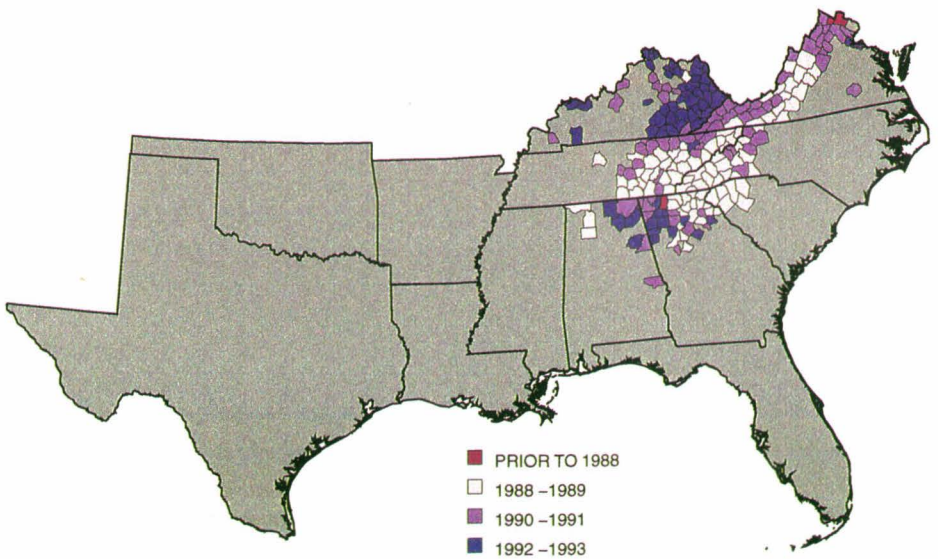
Figure 6 shows the spread of the disease from 1988 to 1994 for counties in which suspected dogwood anthracnose infections were confirmed through laboratory cultivation of the fungus. Initial data were supplied by numerous State and Federal cooperators.

Dogwood anthracnose will intensify in the future. Losses will continue to be heaviest at higher elevations and on shaded, north-facing slopes. Eventually, trees in the forest setting will be largely eliminated above 3000 feet. Trees in full sun exposure below 3000 feet will sustain little damage. The disease is not expected to cause much damage in the coastal plain.

Shade and landscape trees will incur fewer losses because conditions are less favorable to the disease and because fungicidal and cultural control methods are highly effective in protecting these valuable trees.

No special technological advances that will facilitate dogwood anthracnose surveys and confirmation appear imminent. Nevertheless, as the public becomes increasingly aware of the disease, the frequency and accuracy of reports is likely to increase.

Figure 6



Gypsy Moth

The gypsy moth was first introduced from Europe into the United States in Massachusetts in 1869. Since then, it has steadily expanded its range north, west and south. Since the adult female does not fly, dispersal is accomplished via wind dissemination of the small caterpillars. Before 1965, the pest expanded its range by 3 to 9 km (2 to 6 miles) per year. Since then, it has averaged 21 km (13 miles) per year.

Human beings have undoubtedly increased the rate of spread of the gypsy moth. An example is the Blue Ridge Parkway, an area where traps have produced an inordinately high number of catches. In this case, newly hatched larvae have landed on automobiles and trailers and have been transported southwest by motorists.

The gypsy moth entered the Southern Region in the early 1980's. In Virginia, 452,745 acres were defoliated in 1994. The moth has moved steadily along the eastern seaboard into northeastern North Carolina and southwest along the Appalachian mountain chain in Virginia.

The gypsy moth produces one generation per year. Larvae begin emerging from egg masses in April or early May, usually completing their development by late June. They seek sheltered areas in which they pupate for about two weeks. ***Figure 7*** shows a late-stage larva.

Adult male moths are dark brown with many dark bands across the forewings. The nearly white females are flightless because they are so heavily laden with eggs. They crawl short distances from the place where they emerge to release a potent pheromone to attract males. After mating, the female deposits her eggs in a single mass that contains from 75 to 1,000 eggs and then dies. Larvae hatch the

following spring.

Gypsy moths feed on a wide variety of trees, shrubs, and vines. Preferred hosts include all oak species, sweetgum, apple, beech, birch, basswood, and willow. Hosts intermediately favored include maple, hickory, black cherry, elm, sassafras, all pines, eastern hemlock, and black gum. Least preferred are ash, yellow-poplar, redcedar, sycamore, dogwood, American holly, and black locust.

Defoliation by the gypsy moth can result in growth loss, crown dieback, and tree mortality. Trees that have been defoliated begin the next year with much lowered food reserves and are far more vulnerable to other insect and disease pests. Tolerance for defoliation varies greatly, with dominant trees on good sites able to tolerate defoliation. Weaker trees often succumb the second year.

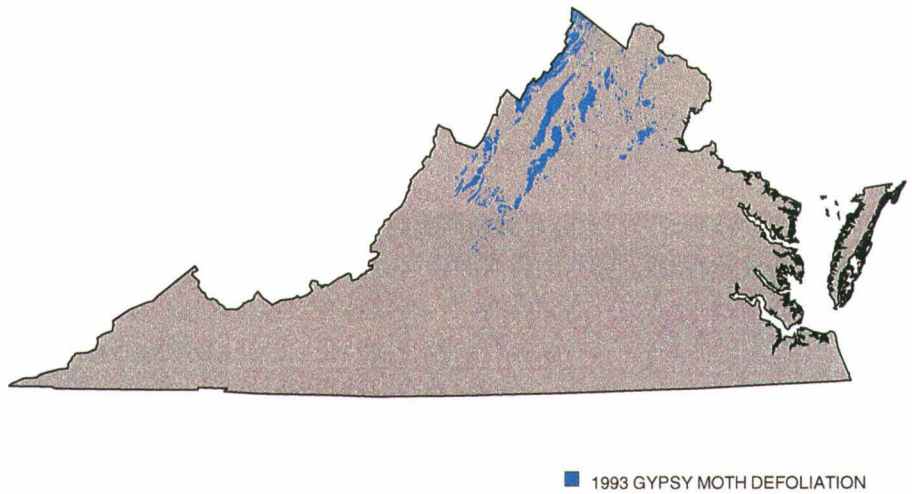
Survey information on the gypsy moth is compiled in two very different ways. The first is through trap catches, and the second is by defoliation mapping.

In the first method, male moths are lured to and trapped in boxes baited with synthetic sex pheromone. Pheromone trap grids can yield valuable information on isolated infestations beyond generally infested areas. In 1994, such a system revealed heretofore unknown infestations in Arkansas, Tennessee, Georgia, and North Carolina.

Gypsy moth defoliation maps are compiled in several ways, principally sketch mapping, videography, and aerial photography. Over 452,000 acres were mapped as "defoliated" in Virginia in 1994, a decrease from 1993 ***(Figure 8)***. The map was prepared from information supplied through aerial surveys by the Virginia Division of Forestry, USDA Forest Service, and other sources. No defoliation from gypsy moth occurred in other Southern States.

Scientists estimate that the entire area of the gypsy moth host type in the East, through eastern Texas and northern Florida, will be infested by the year 2160. However, this rate could be increased by a new complicating factor. A new strain of gypsy moth recently was introduced on the North Carolina coast. The females of this strain are able to fly, thereby theoretically greatly increasing the ability of the species to disperse more rapidly. Additional information on this new strain is given in the section of this publication on localized stressor activity.

Figure 8



Monitoring of gypsy moth defoliation will improve as sketch mapping is replaced with better technologies. Already, the cost of videography is declining, with several State agencies planning to purchase this equipment that is less expensive and more cost effective.

A French scientist deliberately brought egg masses of the gypsy moth into the United States with the hope of crossing the species with the silkworm. In the course of his research, larvae escaped and formed the nucleus of an outbreak that eventually would grow into one of America's best known pests.

Oak Decline

The oak resource in the southern United States is significant. Approximately two-thirds of the hardwood forest is classified as upland hardwood, where a malady known as "oak decline" is most prevalent.

Oak decline has been reported in the United States for over 130 years. It is a syndrome that involves the interaction of predisposing factors such as climate, site quality, and tree age. Drought and insect defoliation escalate the condition. Pests such as armillaria root disease and the two-lined chestnut borer, which are ordinarily nonaggressive pests on vigorous trees, successfully attack trees stressed by oak decline. Decline is characterized by a gradual, but progressive, dieback of the crown ***(Figure 9)***. Mortality typically results after several years, with mature overstory trees the most heavily afflicted.

Forest Inventory and Analysis units maintain data sets that are useful in assessing oak decline on a regional scale. FIA plots were classified as meeting the definition of "upland oak" and "bottomland oak." Plots also were classified as meeting the criteria for

Figure 9

being vulnerable to oak decline syndrome.

In 1993, analysis of data collected by FIA revealed that over 3.9 million upland hardwood acres and 0.4 million bottomland hardwood acres were affected by oak decline. Incidence, expressed as a percentage of the vulnerable host acres, was 9.9 percent for upland types and 6.2 percent for bottomland types.

Figure 10 shows upland areas that are affected by oak decline syndrome as recorded by crews of the Forest Inventory and Analysis group. ***Figure 11*** shows bottomland areas.

For upland types, the highest incidence was in North Carolina and Virginia at over 19%. The lowest incidence for upland types occurred in Oklahoma and Louisiana with less than 3 percent. Incidence in Florida was unexpectedly high at over 18 percent.

For bottomland types, the highest incidence was reported in Florida, followed by Tennessee and Georgia. Louisiana and Mississippi have the largest bottomland resource, yet the lowest incidence (6% and 3% respectively). Sampling errors calculated for the estimates of area affected vary greatly according to the number of affected plots. Reliability of the data is low where few plots exist.

Oak decline probably will increase, particularly where oak forests continue to age. This seems to be the destiny of oak forests throughout much of the South, where harvest and regeneration occur at a low rate.

Future efforts to improve the current monitoring procedure could be aimed at correlating oak mortality with dieback coding to see if the recognition of decline-affected plots can be improved.

Figure 11

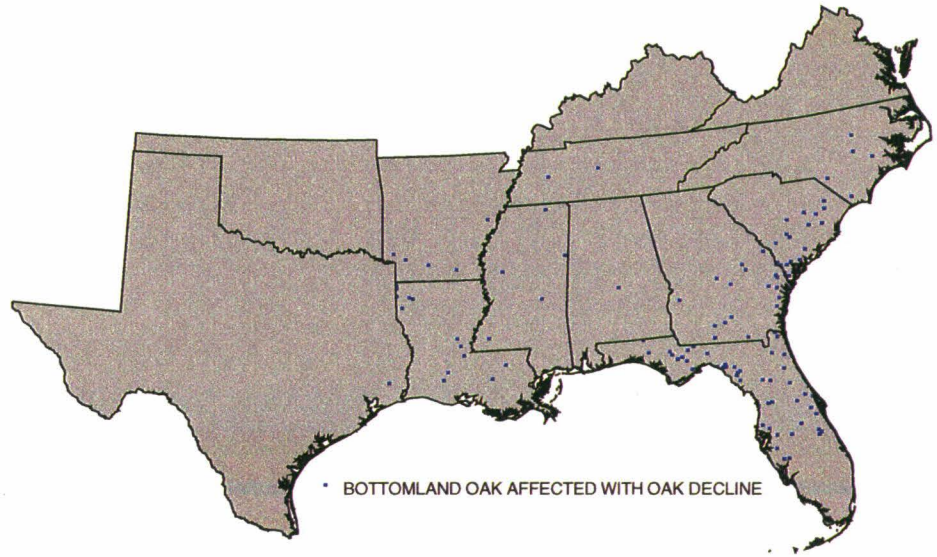
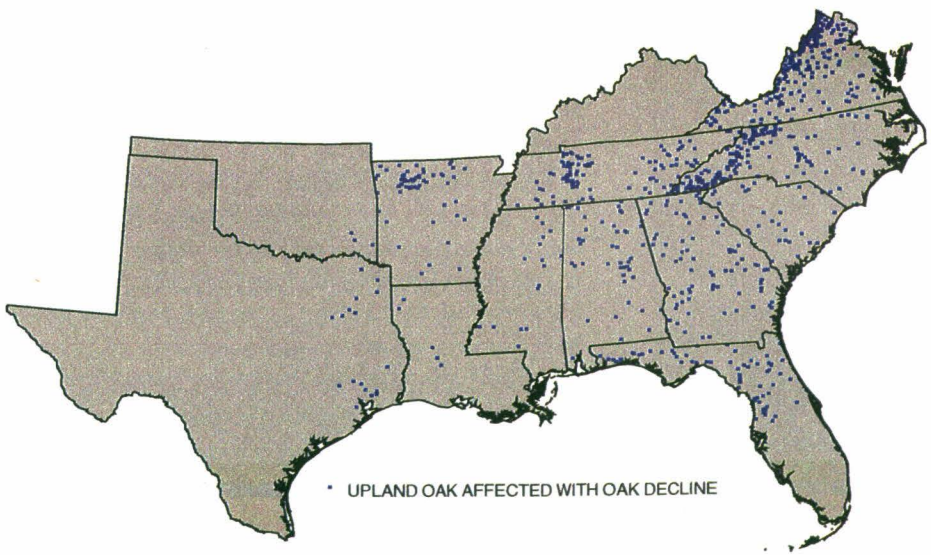


Figure 10



The impact of oak decline is multifaceted. In addition to timber loss, the syndrome results in loss of mast production, with consequential negative impact on wildlife. Other impacts are aesthetic, particularly in the southern Appalachian Mountains, where widespread dieback and mortality affect the quality of scenic vistas.

Stressors of Pine Forests

Four stressors of pine forests emphasized by the Forest Health Monitoring program are annosum root disease, fusiform rust, littleleaf disease, and southern pine beetle.

Annosum Root Disease

Annosum root disease contributes significantly to pine mortality, reduced growth, and increased vulnerability to bark beetle attacks in the South. Fruiting bodies of the disease-causing fungi appear at the root collar and are often obscured by dead needles and soil detritus ***(Figure 12)***.

Figure 12

The first comprehensive survey of annosum was conducted in 1960 by the Southeastern and Southern Forest Experiment Stations. Results of this survey showed 2.8 percent mortality in planted loblolly stands and 2.2 percent mortality in slash plantations. Damage was more severe on sandy soils and former croplands, and damage increased as the number of thinnings increased.

Since the 1960 survey, other studies have shown a significant growth difference between healthy and diseased loblolly trees, with a reported 4 percent per year loss in radial growth and a cumulative 5-year loss of 19 percent. Similar losses have been reported in slash pine plantations affected by annosum root disease. Volume losses within high-risk pine plantations have ranged from 0.1 cord per acre per year to 0.5 cord per acre per year over the first 5 to 9 years after initial thinning.

Although the disease is most often associated with thinned plantations on sandy, drained sites, it can be found on a variety of sites, soils, and forest conditions. The primary pine hosts include loblolly, longleaf, shortleaf, slash, and white pines. Slash and loblolly are the most commonly planted species in the South, and both are very susceptible to annosum root disease.

The primary risk factors associated with annosum root disease include the amount of host type available, timing and degree of management activity, and the soil-site conditions. Annosum spores colonize freshly cut stumps. The fungus grows through the root system and into adjacent healthy trees through root contacts and grafts. Within the Southern Region, there are an estimated 163.5 million acres of high and moderate risk sites.

Sites classified as high risk are well-drained soils containing sand within the upper surface layers of 10 inches and greater. Increased annosum risk also has been attributed to reduced organic matter and high pH range in the soil. Soil variables, including organic matter, pH, and texture, are the factors considered most likely to influence host resistance, as well as the root-infecting fungi or soil-inhabiting microorganisms that may compete with annosum. These risk factors are used to predict the rate of spread if a stand becomes infected with annosum root disease.

Variables such as weather patterns, management intensity, species composition, and site productivity all influence host susceptibility to root disease.

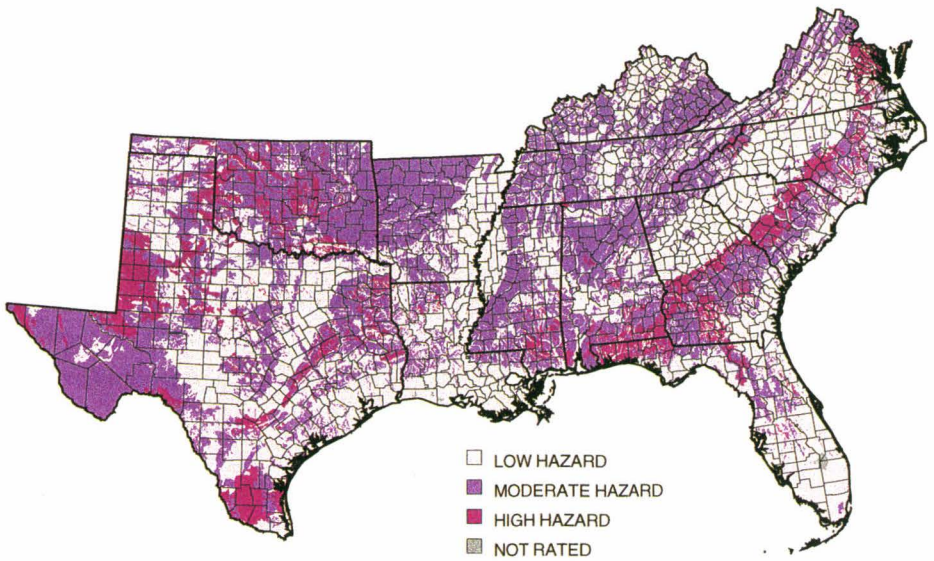
Risk of damage caused by annosum decreases on sites with increased clay content in the surface layer. Loamy and silt-loam soils are considered moderate risk for annosum development. Clay sites prone to flooding and those that are predominately wet are classified as low-risk sites.

Evaluation of risk factors prior to implementation of management strategies is an effective tool for reducing annosum root disease. Risk evaluations based on soil maps and examination of soil-site conditions enable forest managers to implement preventive measures.

Annosum prevention includes applying a borax formulation to stumps during first thinnings. A second method, using a spore suspension of a competitive fungus, can be applied to stumps during thinnings on sites where annosum is already present in the stand. Other preventive measures include prescribed burning prior to thinning, increased spacing of seedlings when regenerating pines on sites at risk for annosum, and summer thinning from May through August in areas below 34 degrees north latitude.

Evaluation of annosum risk on a regional scale is beneficial for assessing an ecosystem approach or a holistic landscape viewpoint for resource

Figure 13



management. Soil association maps for the Southern States were evaluated for key attributes pertaining to risk factors for annosum root disease. A data base containing polygon coverage of soil types, digitized from State survey maps, was used to prepare the maps.

The regional soil risk map shown in ***Figure 13*** should not be used to evaluate site-specific management areas. County boundaries are shown only to assist in identifying risk areas and do not indicate that all soils and sites are high, moderate, or low risk as identified by the color codes.

Annosum incidence represents the frequency of disease signs and symptoms within a stand, whereas severity is a measure of extent of colonization and degree of root decay within the residual stand.

Fusiform Rust

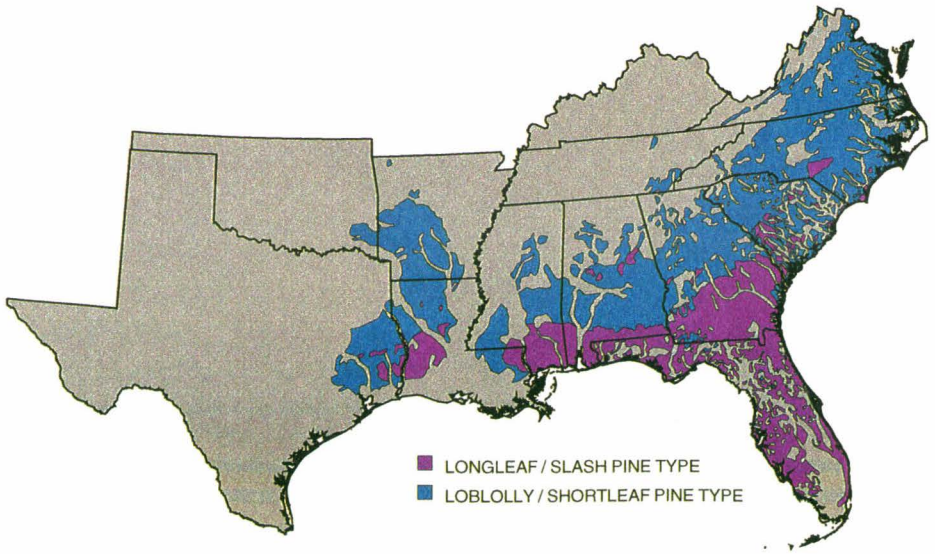
Fusiform rust is the most important pine disease in the South, where about 16.7 million acres of slash and loblolly pine show at least 10 percent of the trees infected. Annual losses are estimated at 47.5 million dollars. ***Figure 14*** shows areas with large stands of loblolly and slash pine.

Before 1930, fusiform rust was found throughout the southern pine resource, but incidence of the disease was low. It increased steadily until it was well established by the 1970's. In the 1980's, the disease continued to increase, but at a slower rate of about 2 percent per year.

Shifts are now occurring where the rust is increasing in some areas, especially where slash and loblolly pine were planted outside their natural range, and along the leading edge of the current disease distribution. The overall trend suggests a slight decrease in infection. This is probably caused by changes in forest management practices and genetic resistance.

Infections that occur on the main stem within the first 5 years of a tree's life normally cause death. Spindle-shaped swellings or galls develop on the branches ***(Figure 15)*** or main stem, with main-stem infections on older trees somewhat depressed on one side. This results in wood quality loss, as well as frequent mortality from main-stem breakage at the site of the canker. Young trees with main-stem infections are often killed by the fungus. Losses in individual stands, as well as in nurseries, can exceed 80 percent. Loblolly and slash pines are the most susceptible species.

Figure 14



By analysis of Forest Inventory and Analysis data, a hazard rating system for fusiform rust was developed for loblolly and slash pine. Three infection classes were established: low, 0 to 9 percent infected; medium, 10 to 30 percent; and high, 31 to 100 percent.

Figure 16 shows fusiform rust hazard for loblolly pine, and ***Figure 17*** shows the hazard for slash pine.

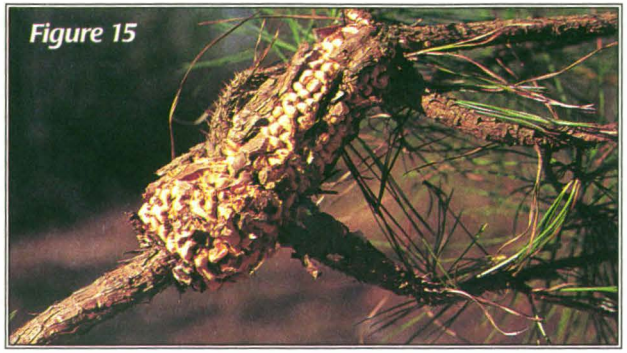


Figure 15

Maps were prepared using FIA plot data. All loblolly and slash pines 1 inch dbh and larger were examined for fusiform rust. Natural stands from 5 to 15 years old, and planted stands with at least 30 percent infection, were used to develop the maps.

As indicated by ***Figure 16***, rust on loblolly pine is most common in the Piedmont and coastal plains of Alabama and Georgia and in northern Florida. In these areas, 16 percent of loblolly is classified as high hazard. Georgia, which has the most loblolly pine acreage (5,753,000 acres), has the second largest percentage of high-hazard sites for loblolly.

Figure 17 shows that fusiform rust on slash pine is most common in north central Florida, southern Georgia, and areas outside the tree's natural range. About 50 percent of slash pine is classified as high hazard. Florida, with the most slash pine acreage (5,198,000 acres), has the lowest percentage of high-hazard sites for slash.

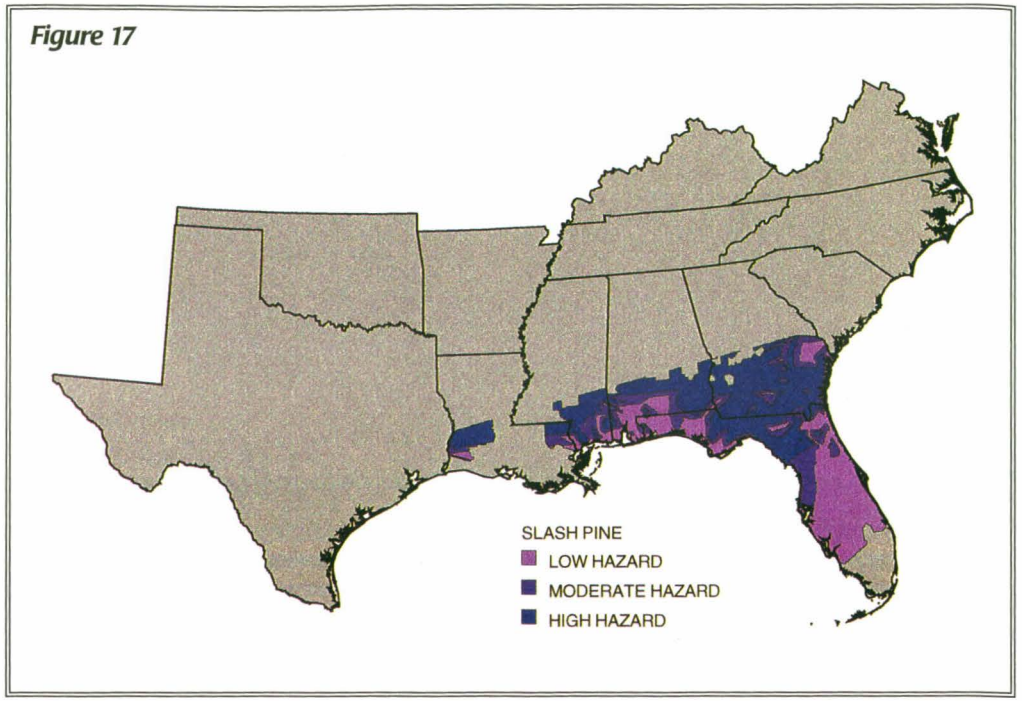


Figure 17

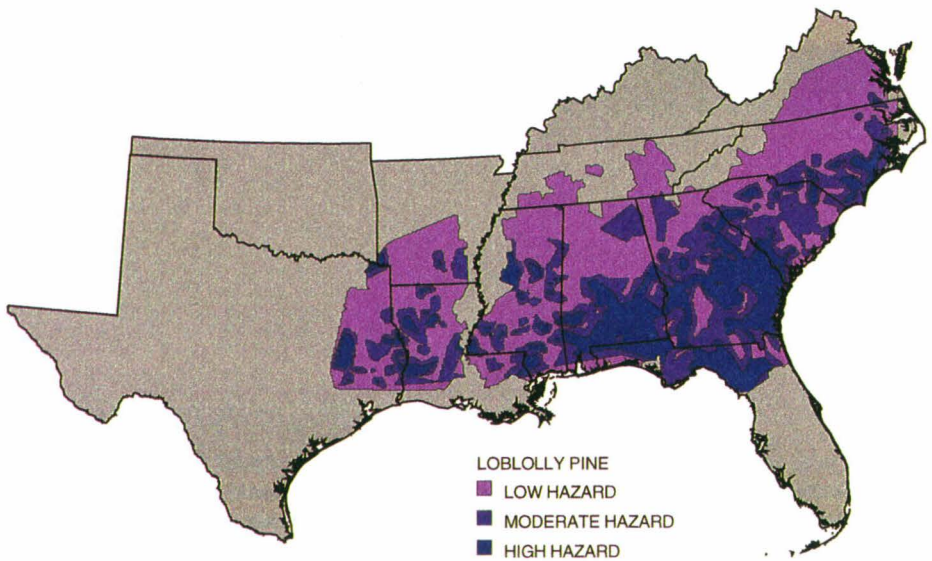


Figure 16

Because of genetic factors, individual trees vary greatly in their susceptibility to fusiform rust. Building on these genetic differences, the Resistance Screening Center in Asheville, North Carolina, annually screens several hundred loblolly and slash pine seedlots for their susceptibility and resistance to the disease. By constantly selecting trees for resistance, foresters are able to greatly reduce the impact of this serious pest generation after generation.

Littleleaf Disease

Littleleaf disease (LLD) affects shortleaf and loblolly pines in the Piedmont plateau of the southern United States. It is caused by a soil fungus that attacks the feeder roots of older trees growing in eroded soils with poor internal drainage. Feeder roots are killed at a faster rate than the tree can generate new ones, and tree growth slows.

After several years, infected trees show sparse and yellow crowns of dwarfed and tufted needles ***(Figure 18)***. Abnormally

large cone crops of undersized cones are often produced. The cones contain smaller seeds with decreased viability. These distress cone crops are indicative of the tree's loss of recuperative vigor. Eventually, affected trees die, either from the disease alone or from increased susceptibility to pine bark beetles, particularly the southern pine beetle.

The historical range of LLD encompasses 177 counties comprising some 50 million acres from Mississippi to Kentucky and Virginia ***(Figure 19)***. This range represents the largest area where older, susceptible pines and littleleaf-disease soils once coincided. The area was determined from the historic distribution of LLD described in published literature and from consultation with State and Federal cooperators.

Figure 18

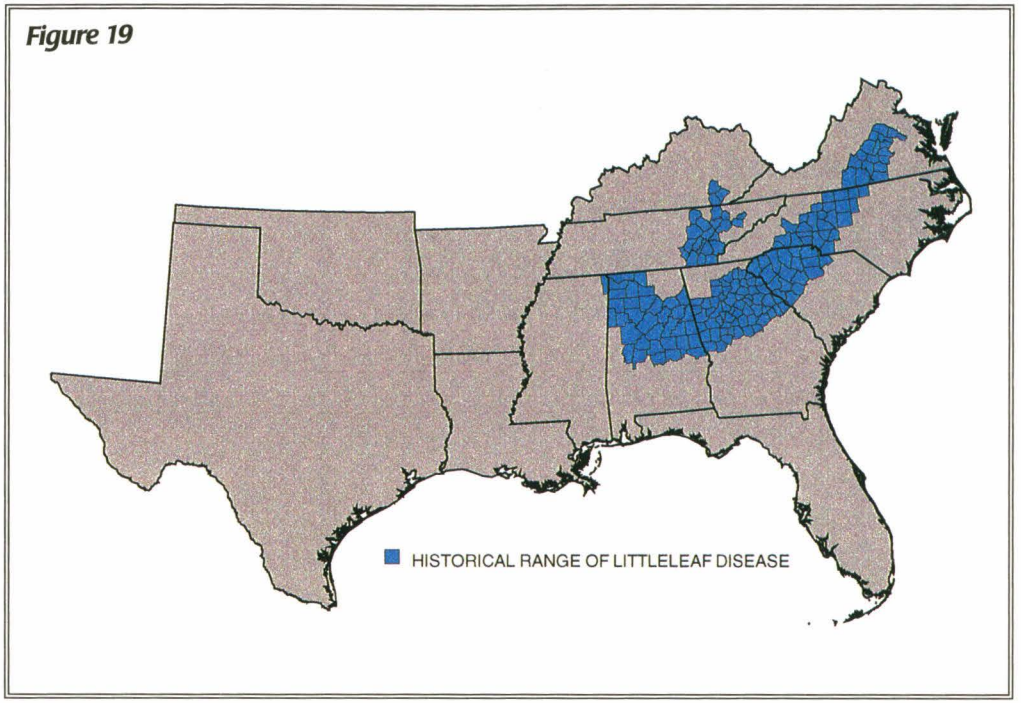


Figure 19

Today, high and moderate risk soils predominate in 125 of the counties in the historical range of LLD, with a total of 33.6 million acres. The soil hazard for LLD was determined from State soil maps.

At present, 87 of these 125 counties with high- and moderate-risk soils have low LLD potential because they have a low volume of loblolly plus shortleaf, defined as less than 100 cubic feet per acre. Data on volume were from work units of Forest Inventory and Analysis of the Southeastern and Southern Forest Experiment Stations. These counties were identified by overlaying data for host type within the disease range on counties with predominately high- and moderate-risk soils. The LLD potential could increase in these counties if pine volume increases in these areas.

In only ten of the 125 counties, totaling 3.6 million acres, does high volume of loblolly plus shortleaf pine coincide with littleleaf soils. For this analysis, high volume was defined as more than 200 cubic feet per acre and is used as a surrogate for older, littleleaf-prone trees. The ten counties with the highest LLD potential, shown in ***Figure 20***, are located in Alabama, Georgia, and South Carolina.

This hazard rating is based on Forest Inventory and Analysis data and on soil information. Its accuracy is directly related to the completeness and accuracy of these information sources. Further refinement might be made by enhancing pine-volume maps with information on size and age classes that gives a better indication of prime susceptibility. Soil survey data collected consistently with identical intensities in all States would also improve overall quality. With the passage of time, we can expect to witness these improvements.

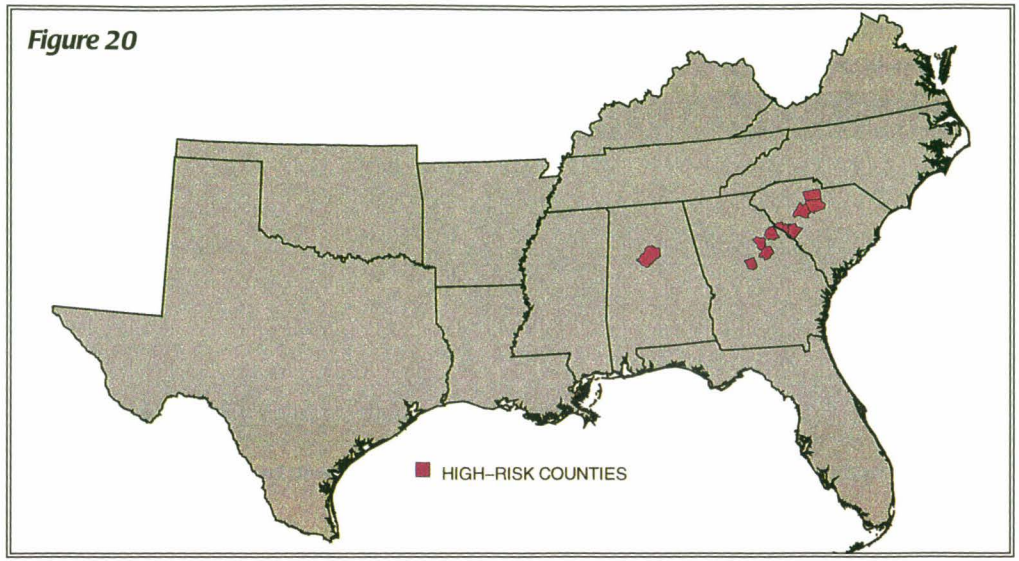
Littleleaf disease probably will continue to decrease on private land because the trend for industrial owners is toward shorter rotations, thereby avoiding older stands prone to the disease. Control of tree density and species composition through artificial regeneration will also contribute to this downward trend. Further, increasing urbanization in the Piedmont region probably will divert land from

Littleleaf disease is a condition with its origins in human land-use practices. Most of the areas exhibiting severe littleleaf symptoms today were improperly farmed in the period from the late 1800's up to the 1930's, resulting in severe soil erosion. In the 1950's, large forests on such Piedmont land were bought by the Federal government, converted to national forests, and planted with pines known as "Eisenhower pines" because of the administration at that time. So badly depleted is the land in some places that even southern pines, notorious for their ability to tolerate poor site conditions, succumb to strains associated with such a stressful environment.

forest uses and reduce the acreage of high-hazard soils that support susceptible pine types.

In contrast to private land, the trend on public land is toward longer rotations and increasing noncommodity uses, such as recreation and wildlife habitat. On these lands, LLD will probably continue to be a significant management concern as stands age. If susceptible shortleaf and loblolly pines are regenerated on public lands where the objectives are continued long rotation for wood products and noncommodity values, LLD will surface as a management concern as these stands approach vulnerable ages. If no intentional pine regeneration is undertaken, then low-quality hardwoods that are immune to LLD will gradually dominate the landscape as pines are replaced by the combined effects of nonintervention, LLD, and fire control.

Figure 20



Southern Pine Beetle

The southern pine beetle (SPB) is one of the most serious insect pests of pine in the South. Smaller than grains of uncooked rice, these hard bodied, dark brown insects annually destroy timber trees worth millions of dollars. Additional impacts are on recreation areas, shade trees, and general aesthetics.

The beetles bore directly through the tree bark, normally producing pitch tubes that resemble kernels of popped corn. Females construct long, winding, S-shaped tunnels between the bark and wood. Lined with eggs, these tunnels eventually girdle the tree, effectively stopping the flow of water and nutrients. The beetles also introduce a fungus known as "bluestain," which furthers damages the conductive systems of the tree by plugging cells. ***Figure 21*** shows beetle egg galleries and bluestain streaking on the sapwood. Newly emerging beetles bore directly through the tree bark, leaving innumerable holes and making the tree appear as if hit with bird shot.

As a result of the damage to the phloem, trees eventually fade to yellow, and then bright reddish brown before they lose their needles. Typically, the direction in which the infestation or spot is spreading can be determined by tree color, with more recently attacked trees (which comprise the spot head) appearing abnormally light green to yellow, and trees with older infestations appearing red or gray. Beetle spots can vary in size from just a few trees to thousands of acres.

The number of generations of beetles per year depends on several factors, including location and weather conditions. Under conditions favorable to the insects, as many as seven generations per year appear in certain parts of the South, with the life cycle being completed in as little as a month.

Typically, infestations begin in trees weakened by such stress factors as disease, lightning strikes, excessive age, or storm damage. Once the beetles become established in such trees, they are capable of attacking

Figure 21

apparently vigorous, healthy hosts.

While SPB infestations come and go across the South, the insect is almost always epidemic somewhere in its natural range. Reliable records on southern pine beetle infestations have been available since about 1960, with certain parts of the South (e.g., eastern Texas and northwestern South Carolina) showing an inordinate predisposition toward outbreaks.

Since 1960, the USDA Forest Service has requested cooperating State agencies to report counties exhibiting more than one multiple-tree SPB spot per 1000 acres of host type, with host type determined by Forest Inventory and Analysis survey data. Additionally, Forest Service land managers reported the same data. The information was then compiled by frequency of incidence.

Figure 22 shows, by county, the number of years in which SPB has reached outbreak status since 1960.

Southern pine beetle infestations have been at the root of controversy in Texas since about 1985. Wilderness areas, consisting of large, old, highly susceptible monotypic stands of southern pine, have generated massive SPB infestations. Adjacent private landholders complain that regulations prohibiting adequate control within the wilderness areas have resulted in severe losses on their lands from spreading infestations.

Due to the cyclical nature of SPB epidemics, the South will doubtless continue to sustain periodic heavy losses from the pest. Typically, these outbreaks last two to three years, and repeat about every seven years. Long-term losses may decline slightly because of improved management methods that stress loss prevention, including increased stand and age diversity, and better detection and control practices.

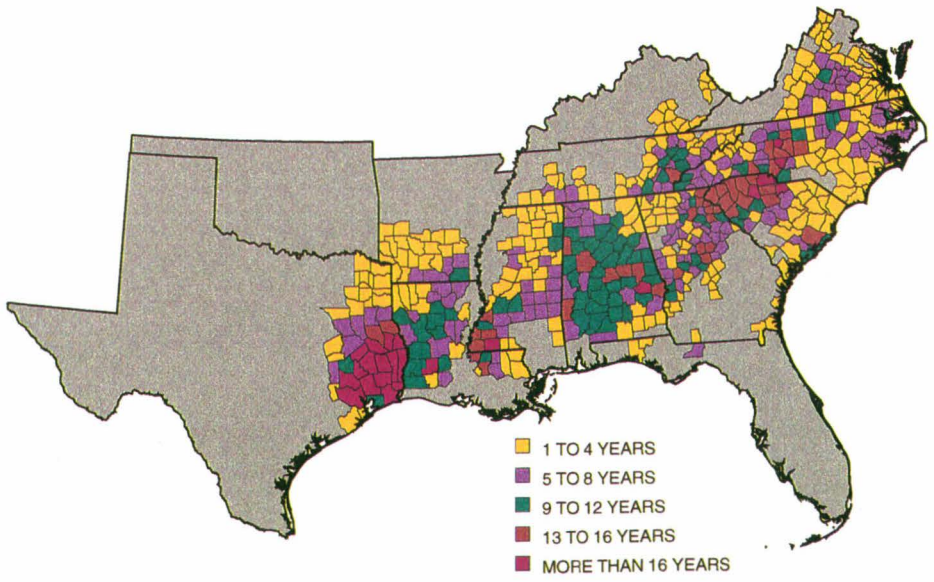
The principal method for SPB surveys remains the traditional aerial sketch map survey, a procedure highly dependent upon the skill and experience of surveyors to accurately plot infestation locations. Promising new technologies, however, will doubtless find applications in SPB detection and evaluation. These technologies include global positioning systems (GPS), satellite imagery, and aerial videography.

The GPS uses a network of satellites that allows survey crews to determine location within as short a distance as 3 meters. It will allow even inexperienced sketch mappers and ground check crews to find spots quickly, easily, and more economically. Surveyors envision a time when aerial survey crews can mark SPB infestations using aircraft-based GPS, and ground crews can, in turn, use terrestrial units to travel directly to the spots.

Additionally, declassified satellite imagery is expected to improve to the point that photographs will be far superior in resolution to those of today, probably eventually allowing for real-time transmission of SPB data.

Finally, emerging technologies such as aerial videography, in combination with such advances as GPS, will enable survey crews to make meaningful progress in their ability to detect and evaluate southern pine beetle infestations.

Figure 22



Stressors of Spruce-Fir Forests

In the South, stands of spruce and fir typically are found at higher altitudes in the Appalachian Mountains. A stressor emphasized by the Forest Health Monitoring program is the balsam woolly adelgid (BWA).

Balsam Woolly Adelgid

Introduced into Brunswick, Maine, in 1908, the balsam woolly adelgid first appeared in the southern Appalachian Mountains in the 1950's. The pest has also found its way into the Pacific Northwest. In the eastern United States, the adelgid feeds on balsam and Fraser firs.

Vast stands of Fraser and balsam fir have been killed throughout much of these species' range in the East. Since fir primarily is found in high-altitude scenic areas of the South, most of the impact by the pest is on aesthetics and recreation.

The complex and interesting life history of the balsam woolly adelgid is simplified somewhat in the following description. Full-grown adelgids are microscopic, but their white, waxy, threadlike covering makes them appear as dots of "wool."

In the late spring and early summer, a group of yellow-brown eggs is deposited and attached to the bark behind the female's body by a minute thread. These eggs hatch into mobile crawlers that actively search out suitable feeding places. Because crawlers are so small, dispersal is further aided by wind, although only a small percentage of them find their way to other trees.

Once a crawler finds a suitable feeding site, it inserts a stylet through which it extracts juices from its host. The stylet is several times longer than the crawler's body. Soon after beginning to feed, the insects excrete waxy "ribbons" from their backs and sides. Eventually, they are completely engulfed in this protective woolly mass. By this time, the adelgids are immobile, a condition which lasts for life.

Interestingly, there are no known male balsam woolly adelgids in North America. All reproduction is parthenogenic, that is, achieved without fertilization by males. Adelgids produce two, and occasionally three, generations annually in the South.

Although not a direct cause of tree mortality, feeding by the balsam woolly adelgid causes gout, a syndrome characterized by enlarged nodes and buds. When feeding begins, the adelgid injects a saliva into the tree to facilitate uptake of materials. This substance is toxic to cell tissues. A form of wood resembling compression wood forms at the attack sites. Called "rotholtz," this type of wood forms greatly thickened cell walls that interfere with translocation of water and nutrients, thus starving the tree.

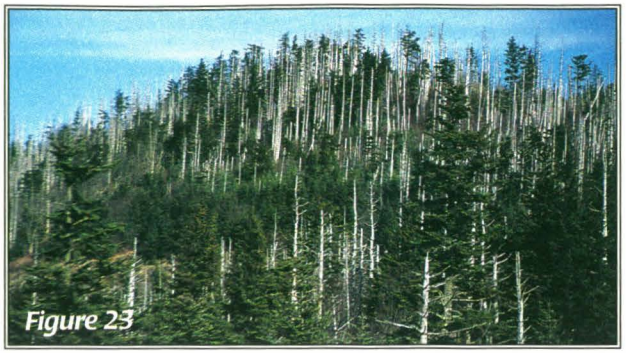


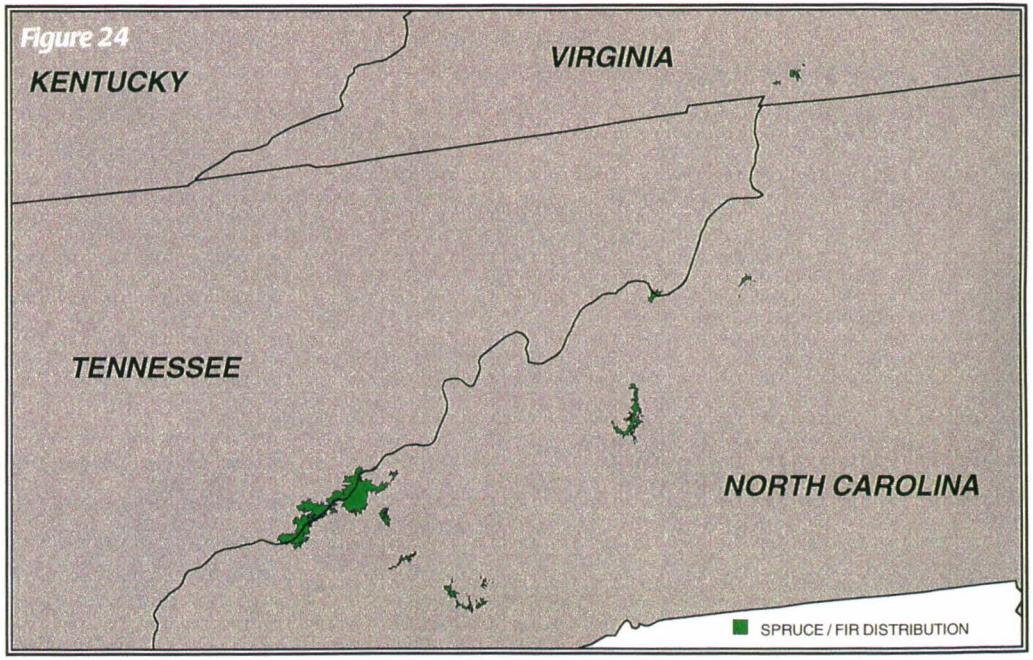
Figure 23

The BWA attacks Fraser fir on any wood surface. Twigs, branches, and the bole are all suitable feeding sites. Trees of all ages are attacked, but damage is usually minimal until the tree reaches maturity in about 30 years. Decline after about three decades is far short of the tree's normal life span of about 150 years. Fir usually have an opportunity to produce one or two seed crops before succumbing to severe decline and ultimately mortality. This reproduction ensures the maintenance of the fir component in the forest type but greatly reduces the age structure.

Typically, trees with advanced infestation exhibit top kill. Eventually, needles turn red and fall off. Stands killed by the balsam woolly adelgid are characterized by trees in various stages of decline, including snags and spiked-top individuals adjacent to more recently infested red-needled trees. ***Figure 23*** shows snag stems of firs killed by the balsam woolly adelgid standing among healthy trees.

As the balsam woolly adelgid continues to spread throughout southern spruce-fir stands, older trees will be increasingly replaced by younger individuals. Red spruce, a species immune to attack from the BWA, will make up a greater part of the spruce-fir type.

In the past four decades, the balsam woolly adelgid has spread to every fir stand in the southern Appalachian Mountains. A reasonably accurate distribution map of the insect can be produced by simply plotting the location of its host. ***Figure 24*** was produced from Forest Inventory and Analysis data on spruce-fir distribution.



Damage by the balsam woolly adelgid is often misreported by the media as the effects of "acid rain." While there may be a link between acid precipitation and a predisposition for attack by the balsam woolly adelgid and other insects and diseases, there is little doubt that the BWA is the principal causal agent for most of the damage to fir trees in the southern Appalachian Mountains.

Other Stressors

Other stressors emphasized by the Forest Health Monitoring program include weather, ozone, and the hemlock woolly adelgid.

Weather

Weather has been associated with forest processes for many years. For example, the Europeans began to record their thoughts on how weather and the forests interacted by the early 1200's. Weather is occasionally directly responsible for devastation of forests through flood, high wind, lightning, or severe drought. It is a major driving force behind wildfire, insect, and disease outbreaks, as well as seed dispersion and tree growth.

Tree growth is the result of complex interactions among many physical, chemical, and biological processes. Weather is the major uncontrollable or unknown factor influencing growth. Unfortunately, there is no definitive model that uses weather to predict tree growth. There is, however, general agreement that precipitation, relative humidity, and temperature are the major driving weather variables, with wind perhaps a major indirect influence.

The weather data contained in the GIS used by Forest Health were purchased from the National Climactic Data Center in Asheville, NC. Data were decoded, edited and summarized by James T. Paul, forest meteorologist (retired), and James K. Forbus, systems analyst, both of the USDA Forest Service, Macon, Georgia. The process required several years to complete. These data are unique because considerable effort was expended to detect and correct errors and because the monthly averages and deviations from a long-term average (1951 through 1990) are available in gridded format.

Climactic variables included in the GIS are: precipitation, maximum and minimum daily temperatures, relative humidity, wind speed, and freezing precipitation. Data from 98 weather stations in the South were used to summarize relative humidity and wind speed. Precipitation records from 994 stations were summarized, as were maximum and minimum temperatures from 537 stations. After error processing, monthly means and deviations from the monthly mean were computed by year. These data were interpolated to a 0.5 degree grid, using the seven nearest stations.

Figure 25

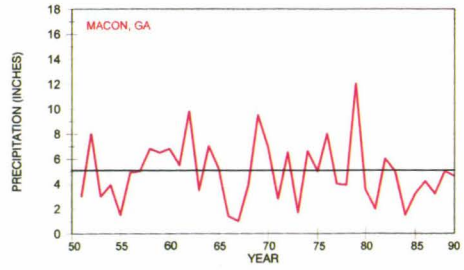


Figure 26

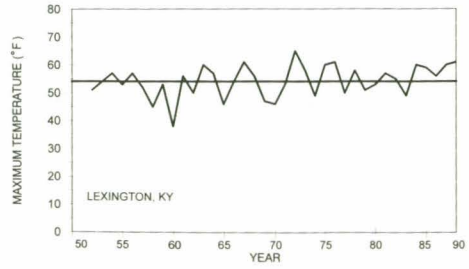
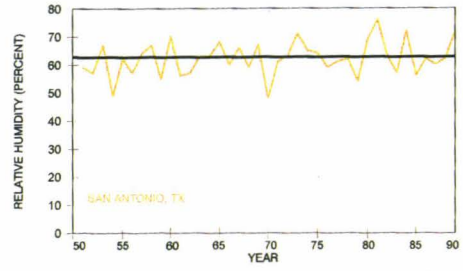
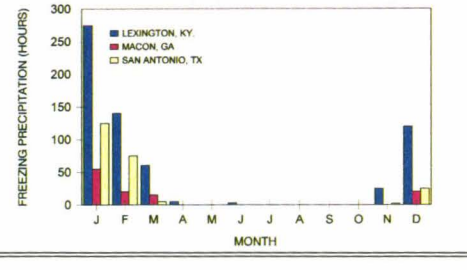


Figure 27



The plotted data in the following examples are typical of weather data summaries available. They include March precipitation for Macon, Georgia ***(Figure 25)***; March maximum temperatures for Lexington, Kentucky ***(Figure 26)***; March relative humidity for San Antonio, Texas ***(Figure 27)***; and freezing precipitation for all three locations, based on the 1951 – 1990 mean ***(Figure 28)***.

Figure 28



March was chosen because new growth is being initiated for many tree species, it is a high-fire-risk month, and various fungal spores and seeds are disseminated by the wind during March. Freezing precipitation was plotted for all 12 months.

When interpreting data like the variables shown in the four figures, or extrapolating to other situations, the reader should be aware of several factors.

Precipitation associated with fronts is usually fairly uniform over large areas. The average thunderstorm cell is about 10 miles in diameter, and this relatively small size results in very localized precipitation patterns. Heavy rain may occur under a thunderstorm cell, but just a few miles away none may be observed. March is a month when both thunderstorms and frontal precipitation are common in Macon. Consequently, one should be cautious in extrapolating precipitation.

The precipitation and temperature data came from the cooperative observer network and included numerous substantial discrepancies between the hard copy and the magnetic copy. From discussions with the National Climactic Data Center staff, it was assumed that the hard copy contained the correct data, and the magnetic record was manually edited to agree with the hard copy. This editing process was labor intensive and very time consuming, but it was necessary to assure a data set largely free of errors. Errors per station ranged from 5 to 15 percent, with an average of about 7 percent. After manual editing, errors were reduced to less than 0.05 percent.

Maximum temperature commonly occurs in the middle or late afternoon when strong horizontal and vertical mixing usually are present. As a result, local site factors are minimized, and the maximum temperature at a point can be used to represent conditions over an area of 10 to 20 square miles with acceptable accuracy.

By using data from surrounding stations, relative humidity can usually be interpolated to an unknown point with an accuracy of about plus or minus 5 percent. This is acceptable accuracy for many purposes.

Freezing precipitation occurs when (1) the temperature of the earth's surface and objects such as trees are at or below freezing, and (2) when falling water drops are supercooled before impacting the earth's surface or other objects. These conditions occur when a cold layer of air near the surface is underneath a warmer precipitation-producing layer aloft. Damage to trees can be substantial, especially if the precipitation is heavy, of long duration, or accompanied by strong winds. In addition to breakage and uprooting, the damaged trees are more susceptible to disease and insect infestation. If the breakage is substantial and widespread, there is an increased potential for subsequent damaging wildfire.

Trophospheric ozone is the most significant regional air pollutant impacting forest health in the South. Ozone is formed by the reaction of nitric oxides and volatile organic compounds in sunlight. These gases are primarily the by-products of anthropogenic sources such as industrial emissions and motor vehicles. High concentrations of ozone are found near or downwind from industrial facilities when geographic or meteorological conditions are conducive to stagnant or low air flow.

Plants that have been identified as reliable indicators of phytotoxic levels of pollutants are known as bioindicators. Examples of bioindicators for ozone include black cherry, blackberry, common milkweed and yellow-poplar.

Figure 29

The most common visible symptom of ozone injury on broad-leaved bioindicator species is uniform interveinal leaf stippling (***Figure 29***). As a gaseous

pollutant, ozone enters the stomata of plant leaves through the normal process of gas exchange, damaging the palisade tissue. Ozone also reduces growth and reproductive capabilities.

Sensitivity to ozone varies between species and within species, mostly because of genetic traits. Site conditions, especially the availability of soil moisture, can also influence the response of plants to injury.

Monitoring and Reporting Ozone Incidence

Ozone monitoring and reporting is a cooperative effort, primarily involving the Environmental Protection Agency, the Electric Power Research Institute, the Tennessee Valley Authority, the National Park Service, and the USDA Forest Service.

The primary sources of information concern hourly mean concentrations of ozone. Similar, although less abundant, data also exist for sulfur dioxide and nitrogen dioxide. These data have been collected from EPA monitoring stations across the South since 1973.

A discussion of procedures can help in understanding the limits and utility of the available data. Monthly ozone air-quality data were characterized as follows: (1) 7-hour average (0900 to 1559) (2) number of hourly occurrences greater than or equal to 80, 100, 120, 140, and 150 parts per billion (ppb).

Earlier reports indicated that ozone concentrations in large city centers were lower than those detected in more rural areas. To determine the relevancy of each monitoring site for the Southern Forest Atlas, large-scale aerial photographs that show land use around each site were obtained. These photos were interpreted by the Aerial Survey Team of the Forest Health Unit in Atlanta, Georgia. Land use was estimated by a quadrant in a 2.5 mile radius around each site. Based on these values, a peer-review panel of scientists decided to use the monitoring sites with forest area of five percent or more and urban area of ninety percent or less. The sites also had to have 70 percent ozone data capture.

These selection criteria resulted in the rejection of approximately 100 site/years of data. The loss of data from these sites created concern as to whether ozone could be characterized throughout the South.

To determine whether or not sites needed to be dropped from the complete data set, kriging interpolation was performed on two subsets of the original data. Kriging is an interpolation technique which uses intersite correlation in the data to determine the weights that are applied to measured values in estimating unknown values. It also quantifies interpolation error, thereby providing a measure of the uncertainty that may arise. Kriging has been widely used to interpolate regional air quality.

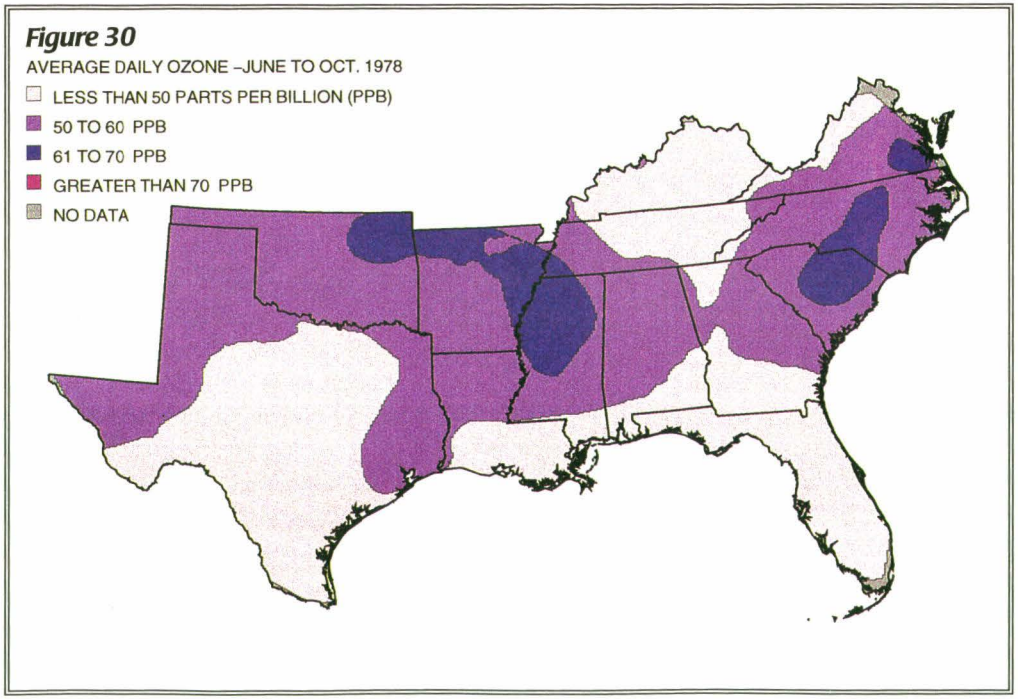
In the first test, kriging was used to predict monthly means of the daily 7-hour ozone values from all monitoring sites for April, July, and August 1984. Results showed that the error of krige estimates compared to the actual values on the selected sites was less than 0.5 ppb. Thus, there was no indication that kriged estimates deviated significantly from actual measures. ***Figure 30*** shows the average daytime concentrations in the South from June through September, 1978, based on data from EPA monitoring stations that were entered into the GIS system.

Ozone Surveys in Wilderness Areas

In addition to surveying for actual incidence of ozone concentrations as described above, the USDA Forest Service also surveys for ozone impact as evidenced by ozone indicator plants in Forest Service wilderness areas. Surveys of ozone injury in the wilderness areas of Southern Region national forests have been conducted periodically according to recommended procedures. One purpose of the surveys is to document visible symptoms of ozone injury as prescribed by the Clean Air Act and other regulatory guidelines. ***Table 1*** shows where surveys of ozone injury have been carried out in class 1 wilderness areas across the South.

Recently published literature predicts an increase in ambient ozone concentrations across the South. This should mean an

Figure 30



The wilderness monitoring program for ozone injury is relatively recent. Trend analysis must await compilation of more data, with establishment of baseline pollutant levels to determine the relative increase or decrease of severity.

increase in visible injury to sensitive plant species. However, the best evidence of trends in ozone injury would be obtained over a relatively long time frame, with foreknowledge of ambient ozone concentrations and site conditions. This approach would require co-locating plots with stationary ozone monitors, and, preferably with plants of known genetic sensitivity.

Our understanding of the mechanisms of ozone-plant interaction continues to evolve rapidly. Consequently, bioindicator plants will doubtless take on increased utility in the years ahead. Additionally, the Forest Health Monitoring program has established a commitment to support ozone bioindicator plants as a meaningful measure of ozone severity. Finally, stations for monitoring ambient air continue to improve, providing data that are more reliable and cost effective.

Table 1.

Wilderness Areas Surveyed for Ozone Injury

	Alabama
Cheaha	
Sipsey	
	Arkansas
Caney Creek	
Upper Buffalo	
	Florida
Bradwell Bay	
	Georgia
Cohutta	
	Mississippi
Holly Springs	
Black Creek	
	North Carolina
Joyce Kilmer-Slickrock	
Linville Gorge	
Shining Rock	
	Texas
Little Lake Creek	

Hemlock Woolly Adelgid

First discovered in the United States in 1924, the hemlock woolly adelgid (HWA) is believed to be an Asian introduction. The insect is a serious pest of both eastern hemlock and Carolina hemlock. In the South, infestations are most prominent in the Shenandoah Valley of Virginia.

Figure 31 shows the range of hemlock in the South, plotted from FIA information. ***Figure 32*** shows HWA occurrence in Virginia by county. The line of infestation was drawn by using the most recent survey data from both the Virginia Division of Forestry and the USDA Forest Service.

The HWA is similar in biology to its relative, the balsam woolly adelgid (BWA). An excellent indication

Figure 31

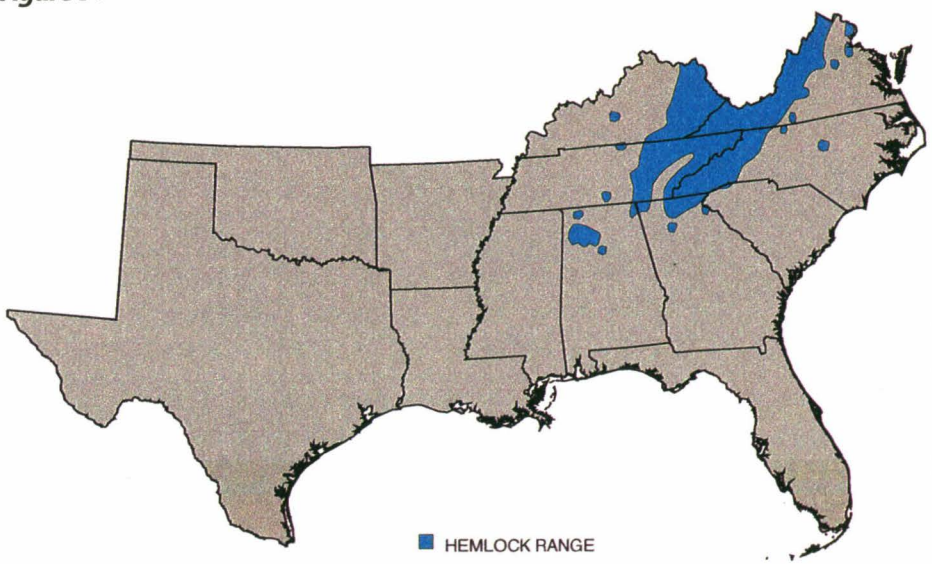


Figure 32

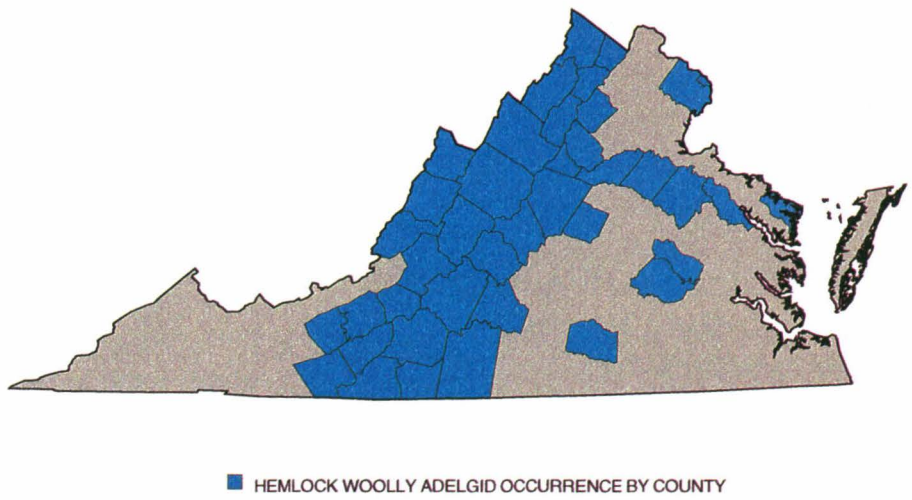


Figure 33

of infestation is the presence of white cottony sacs at the base of the needles ***(Figure 33)***. These sacs are reminiscent of the tips of cotton swabs. Present throughout the year, they are most prominent in the spring.

The HWA feeds during all seasons, with the greatest damage occurring in the spring. The tiny insect is dispersed by wind, birds, and mammals.

Aside from the aesthetic impact of loss of hemlock in scenic areas, campgrounds, and recreation areas, the loss of the species threatens trout survival in some streams. Hemlock limbs hang low over the water of mountain streams, providing an important cooling effect that benefits natural aquatic ecosystems.

The adelgid feeds by inserting its stylet into young twigs, sucking sap, and retarding the growth of its host. Needles become discolored and change from deep green to grayish green, eventually dropping off prematurely. The loss of new shoots and needles seriously impacts tree health, and death can occur within a few years.

The hemlock woolly adelgid will continue to spread southwest along the Blue Ridge Mountains, causing devastation of the hemlock resource in its wake. Many entomologists fear the worst for both eastern and Carolina hemlock, believing that HWA holds the potential for wiping out both tree species.

Localized Stressor Activity

Several stressors of forests in localized areas have received special attention during the last few years. Emphasis in some instances has been on eliminating the pest or limiting its spread. In other cases, emphasis has been on learning more about the causal agents or conditions.

Asian Gypsy Moth in North Carolina

Another introduced forest pest that is closely related to the European gypsy moth has arrived in the South. In June 1993, the Asian gypsy moth was found hitchhiking into the country near Wilmington, North Carolina, on a military cargo ship from Germany.

Unfortunately, the arrival time was during the worst possible period in the insect's life cycle—when moths were mating and in flight. They dispersed at least 19 miles from the docking site.

The Asian strain is more worrisome than the European strain of the gypsy moth that has been in the northeastern United States for many years. The females of the Asian strain, as well as the males, are good flyers. This dramatically increases the likelihood of spread.

In the spring of 1994, the State of North Carolina, with technical assistance from the Federal government, carried out an eradication project over 130,000 acres. The treatment was successful in eliminating the moths from all but a 10,000-acre area. An additional project was planned for the spring of 1995 to rid this small area of moths.

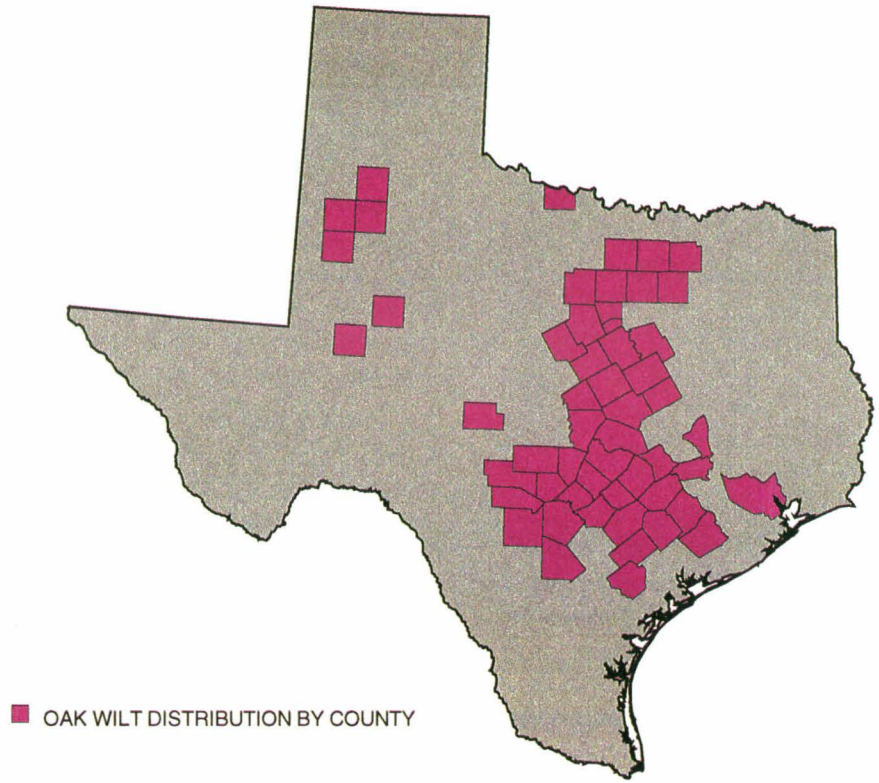
Oak Wilt in Texas

Oak wilt is a systemic, vascular wilt caused by a fungus. Although the disease is known to occur throughout most of the eastern hardwood forest, the only serious epidemic has been in central Texas (and more recently in seven counties in central Minnesota). The disease has caused widespread mortality of live oak and Texas red oak or Spanish oak in central Texas.

The oak wilt fungus was first discovered in Dallas County, Texas, in 1961, but it was not until 1977 that it was identified in central Texas, where the most mortality was occurring. The disease has been confirmed in 55 Texas counties, mostly in the central part of the State ***(Figure 34)***.

The pathogen attacks and kills healthy trees. It can move rapidly from tree to tree through root grafts and common root systems. In central Texas, where large areas of live oaks are often connected to common root systems, very large infection

Figure 34



centers of up to 200 acres have resulted.

The disease is spread longer distances by insects, such as sap beetles, that transport spores from fungal mats produced on dead oaks to uninfected oaks.

Coastal Forest Change in Florida

An estimated 87,000 acres of coastal area on the gulf side of Florida are experiencing an unusual amount of tree mortality. Southern redcedar, cabbage palm, and other tree species are dying along the coastal areas and on associated islands.

The exact cause is unknown, but experts speculate that the problem may be caused by a rise in the ocean level along the affected areas, resulting in salt-water inundation of root systems.

European Gypsy Moth in Arkansas

In June 1992, an isolated infestation of gypsy moth was discovered in Newton County, Arkansas. A 10-acre core of infestation, characterized by extremely high egg-mass counts, was associated with a private residence located 2 miles northwest of the community of Compton.

The Arkansas State Plant Board, in cooperation with the Animal and Plant Health Inspection Service, treated 600 acres of private land with two applications of biological insecticides in May 1993. Post-eradication trapping indicated that the infestation was much larger than originally thought.

In 1994, an aggressive quarantine project was initiated. The quarantine, coupled with another aerial application of biological insecticide on approximately 25,000 acres of land, is expected to be successful in eradicating the infestation.

Glossary

Aerial videography.
Recording of images with a video camera mounted in an aircraft. Videography can be interfaced with other technologies such as GPS and GIS.

Anthropogenic.
Associated with human activity.

Bioindicator.
An organism, usually a plant, with a high and relatively easily identifiable sensitivity to selective environmental influences. For example, black cherry is a bioindicator of ozone pollution.

Bluestain.
A tree-infecting fungus vectored (transmitted) by bark beetles.

Bole.
The trunk or stem of a tree.

Bottomland.
Low-lying land along a watercourse, in contrast to upland.

Bud.
A small protuberance on the stem of a plant that may develop into a flower, leaf, or shoot.

Callus.
A thickened area on bark.

Cambium.
A thin formative layer between the woody element of a plant and the complex tissue containing tubes for translocation of nutrients and water.

Canker.
A localized area of dead tissue in a plant.

Crawler.
An immature insect stage, usually mobile and suited for dispersal.

Dendrochronology.
The study of tree age.

Dieback.
Death of end branches in tree crowns.

Distress cone crop.
An inordinately high production of reproductive structures in conifers, usually associated with a stressed condition.

EPA.
Environmental Protection Agency.

Feeder roots.
Those parts of the root system responsible for assimilation of water and nutrients.

FHM.
See Forest Health Monitoring.

FIA.
See Forest Inventory and Analysis.

Forest Health.
A unit of the USDA Forest Service that specializes in pest and related problems.

Forest Health Monitoring program.
A consortium of many Federal and State agencies that monitors, assesses, and reports on the status of the nation's forests.

Forest Inventory and Analysis.
A unit of the USDA Forest Service charged with compilation and reporting of data on the nation's forests. Formerly called Forest Survey.

Fruiting bodies.
Reproductive structures of fungi.

Geographic information system.
A system of computers and software that stores data and allows analysis of spatial and temporal relationships with one another.

GIS.
See geographic information system.

Global positioning system.
A system that uses satellite technology and portable receiving units to determine location accurately.

GPS.
See global positioning system.

Host type.
A species or group of species attacked by insects or diseases, usually for food. For example, southern pines to southern pine beetles.

Life cycle.
The series of stages in form and functional activities through which an organism passes between successive recurrences of a specified primary stage.

Mast.
Vegetative structures used by wildlife for food. For example, acorns by bears.

Node.
A point on a stem at which a leaf or leaves are inserted.

Off-frame.
Refers to information in the Forest Health Monitoring program not collected as part of the on-frame program. See on-frame.

On-frame.
Refers to a network of survey plots installed at regular intervals across the United States. These plots are administered and monitored by the USDA Forest Service, the Environmental Protection Agency, and participating State forestry agencies.

Overstory.
The layer of foliage in a forest canopy and trees contributing to it. Understory is the term for the plants of a forest undergrowth.

Palisade tissue.
A layer of cells found beneath the outer layer of the upper side of foliage leaves.

Parthenogenic.
Reproduction without intervention by males.

Pathogen.
A specific causative agent of disease.

Perennial.
Present at all seasons of the year. The term can also be used designate a plant that produces new growth in successive years from a perennating part.

Pheromone.
A chemical released by an insect or other animal through which it communicates with another individual of the same species through a sense of smell.

Phloem.
A complex tissue in plants that functions in the translocation of water and nutrients.

Photogrammetrist.
One who makes reliable measurements by the use of photographs, especially aerial photographs.

Phytotoxic.
Poisonous to plants.

Pitch tubes.
Globs of resin that solidify upon exposure to the air. Bark beetles produce pitch tubes through their boring activities.

Pupa.
A transition stage in a life cycle of insects between larva and adult.

Pupate.
To change to a pupa.

Rotholtz.
Hardened reddish wood that results from feeding by the balsam woolly adelgid.

SEFES.
Southeastern Forest Experiment Station.

Sketch map survey.
Determination and delineation of a forest condition by a surveyor marking it on a map, usually from an aircraft.

SOFES.
Southern Forest Experiment Station.

Spore.
A microorganism used to generate a new individual.

Sporulate.
To generate spores.

Spot.
An infestation in the forest, usually referencing a bark beetle infestation.

Spot head.
Part of a spot that comprises the actively spreading portion of the infestation. It is analogous to a fire line in a forest fire.

Stomata.
The plural of stoma, a minute opening in the outer layer of a plant organ, as a leaf, through which gaseous interchange takes place.

Stylet.
A long mouth part of an insect, normally used to extract fluids.

Syndrome.
A group of signs and symptoms that occur together and characterize a particular abnormality.

Troposphere.
The portion of the atmosphere that is below the stratosphere. It extends outward about 7 to 10 miles from the earth's surface.

Understory.
The term for the plants of a forest undergrowth.

Upland.
Ground elevated above the lowlands along watercourses or between hills, in contrast to bottomland.

Vector.
An organism, usually an insect, which transmits a disease.

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Appendix A.

Index of Cited Common and Scientific Names

Pests

Common Name	*Scientific Name**
Annosum root disease	*Heterobasidium annosum*
Armillaria root disease	*Armillaria mellea*
Balsam woolly adelgid	*Adelges picea*
Bluestain	*Ceratocystis minor*
Butternut decline	*Sirococcus clavigignenti-juglandacearum*
Dogwood anthracnose	*Discula destructiva*
Fusiform rust	*Cronartium quercuum fusiforme*
Gypsy moth	*Porthetria dispar*
Hemlock woolly adelgid	*Adelges tsugae*
Littleleaf disease	*Phytopthora cinnamomi*
Oak decline	A complex
Oak Wilt	*Ceratocystis fagacearum*
Southern pine beetle	*Dendroctonus frontalis*
Two-lined chestnut borer	*Agrilus bilineatus*

Hosts

Common Name	*Scientific Name*
American basswood	*Tilia americanum*
American holly	*Ilex opaca*
Apple	*Malus sp.*
Ash	*Fraxinus sp.*
Balsam fir	*Abies balsamea*
Basswood	*Tilia sp.*
Beech	*Fagus sp.*
Birch	*Betula sp.*
Black cherry	*Prunus serotina*
Black gum	*Nyssa sylvatica*
Black locust	*Robinia pseudoacacia*
Butternut	*Juglans cinera*
Carolina hemlock	*Tsuga caroliniana*
Cabbage palm	*Sabal palmetto*
Cucumber tree	*Magnolia acuminata*
Dogwood	*Cornus sp.*
Eastern hemlock	*Tsuga canadensis*
Eastern red cedar	*Juniperus virginiana*
Elm	*Ulmus sp.*
Fraser fir	*Abies fraseri*
Hickory	*Carya sp.*
Loblolly pine	*Pinus taeda*
Maple	*Acer sp.*
Pine	*Pinus sp.*
Eastern red cedar	*Juniperus virginiana*
Red spruce	*Picea rubens*
Sassafras	*Sassafrass albidum*
Shortleaf pine	*Pinus echinata*
Slash pine	*Pinus elliottii*
Southern red cedar	*Juniperus silicicola*
Sweetgum	*Liquidambar styraciflua*
Sycamore	*Platanus occidentalis*
Texas red oak	*Quercus buckleyi*
Willow	*Salix sp.*
Yellow poplar	*Liriodendron tulipifera*

*For diseases, the name listed is the fungus responsible for the pathogenicity.

Appendix B.

Addresses of Southern Region Forest Health Offices and Southern State Forestry Agencies

Southern Region Offices

USDA Forest Service
Forest Health
1720 Peachtree Road, NW
Atlanta, GA 30367

USDA Forest Service
Forest Health
P.O. Box 2680 (28802)
200 W. T. Weaver Blvd. (28804)
Asheville, NC

USDA Forest Service
Forest Health
2500 Shreveport Highway
Pineville, LA 71360

State Agencies

Alabama

Jim Hyland
Alabama Forestry Commission
513 Madison Avenue (36130-0601)
P.O. Box 302550 (36130-2250)
Montgomery, AL

Arkansas

Doug Akin
Arkansas Forestry Commission
3821 West Roosevelt Road
Little Rock, AR 72204-6396

Florida

Ed Barnard/Jim Meeker
Florida Division of Forestry
3125 Conner Boulevard
Tallahassee FL 32399-1650

Georgia

Terry Price
Georgia Forestry Commission
P.O. Box 819
Macon, GA 31298-4599

Kentucky

Mark Matezeuski
Kentucky Division of Forestry
627 Comanche Trail
Frankfort, KY 40601-1798

Louisiana

Rich Goyer/Don Feduccia
Louisiana Department of Agriculture and Forestry
P.O. Box 1628 (70821)
5825 Florida Boulevard, Suite 1068 (70806)
Baton Rouge, LA

Mississippi

Bill Lambert/Evan Nebeker
Mississippi Forestry Commission
301 North Lamar Street, Suite 300
Jackson, MS 39201

North Carolina

Coleman Doggett
North Carolina Division of Forest Resources
Box 27687 (27611)
512 North Salisbury Street (27604)
Raleigh, NC

Oklahoma

Pat McDowell
Forestry Services
Oklahoma Department of Agriculture
2800 North Lincoln Boulevard
Oklahoma City, OK 73105

South Carolina

Mike Remion/Andy Boone
South Carolina Commission of Forestry
P.O. Box 21707 (29221)
5500 Broad River Road (29210)
Columbia, SC

Tennessee

Bruce Kauffman
Tennessee Division of Forestry
Department of Agriculture
Box 40627 Melrose Station
Nashville, TN 37204-4062

Texas

Ron Billings/Joe Pase/Gene Gehring
Texas Forest Service
Texas A & M University System
3rd Floor, State Headquarters Building
College Station, TX 77843-2136

Virginia

Tim Tigner/Joel Artman
Virginia Division of Forestry
P. O. Box 3758
McCormick and Alderman Roads
900 Natural Resources Drive
Charlottesville, VA 22903

Other Forestry Agencies

Puerto Rico

Forest Service, Puerto Rico
Department of Natural Resources
P.O. Box 5887
Puerta De Tierra
San Juan, Puerto Rico 00906

U.S. Virgin Islands

Virgin Islands Forestry Program
Estate Lower Love
Kingshill, St. Croix
U.S. Virgin Islands 00850

Note: Underlined agencies have separate zip codes for mail (usually P.O. boxes) and shipping. Appropriate codes are shown in parenthesis. For example, South Carolina Commission of Forestry is interpreted as follows:

Mail
Mike Remion
South Carolina Commission of Forestry
P. O. Box 21707 Columbia, SC 29221

Shipping
Mike Remion
South Carolina Commission of Forestry
5500 Broad River Road Columbia, SC 29210

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